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THE BLUE BOOK
of
Oil Burning and Burners

A PRACTICAL HANDBOOK COMPILED FOR THE OPERATOR OF OIL BURNERS. IT GIVES INFORMATION ON OIL AND BURNERS, THEIR CARE, OPERATION AND SAFETY HINTS, IN PLAIN ENGLISH

BY

CLAUDE C. LEVIN

Price $2.00

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THIS BOOK IS DEDICATED

TO

JOHN S. MALONEY

A MAN AND AN ENGINEER

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BLUE BOOK

OF

Oil Burning and Burners

HEAT AND COMBUSTION

When we speak of fuel oil we generally mean the oil which is burned in the furnaces of steam boilers.

The best engineer is the one who can make the most steam with the least fuel.

Heat may be produced in many ways, but for the purpose of the marine engineer it is only necessary to consider the heat generated in the furnace by burning fuel oil and coal.

The degree or intensity of heat can be measured by a thermometer or pyrometer.

The quantity of heat necessary to produce a certain temperature is measured in heat units.

The British Thermal Unit (B.T.U.) is 1/180 of the amount of heat necessary to raise one pound of water from a temperature of 32° F to 212° F. Roughly one B.T.U. will raise the temperature of one pound of water one degree.

Above 212°, water is changed into steam, by the addition of heat and the above definition is not true of steam.

The best fuels contain the most B.T.U.'s per pound. The average good steaming coals contain between 11,000 and 14500 B.T.U.'s per pound, while fuel oils contain as high as 20,000 B.T.U.'s per pound.

Unfortunately, there is no quick practical method by which the engineer can judge of the quality of his fuel. The number of heat units per pound must be determined in a laboratory with an instrument called a calorimeter, and to be of any value the test must be very carefully and accurately made.

Consequently the engineer must judge of the quality of his fuel by its actual performance in his furnace. But a knowledge of the fundamental principles of heat and combustion cannot fail to help in saving at the fuel pile.

Heat is generated by combustion, or the burning of coal or oil in the furnace.

Coal and fuel oil consist principally of carbon, oxygen and hydrogen, and a few other elements in small proportions. But as far as heating value is concerned the carbon and hydrogen are the important parts. The duty of the engineer is to understand and provide, as nearly as possible, for the complete burning of all of the combustible parts of his fuel in order to produce the maximum heat.

Air is necessary for combustion. Air consists mainly of two gases, oxygen and nitrogen, in the proportion of 23% oxygen and 77% nitrogen, by weight.

There are also other gases in air, but in neglible amounts. Whereas coal and fuel oil are chemical compounds, air is simply a mechanical mixture.

Oxygen is the element that makes combustion possible. The combustion of coal or oil is complete when all of the contained carbon is *burned into a gas* called carbon dioxide, and all of the contained hydrogen is burned into water.

Carbon dioxide (CO^2) consists of one part of carbon and two parts of oxygen.

Water (H^2O) consists of two parts of hygrogen, and one part of oxygen, and if the two gases, which are invisible, are mixed in the above proportions, and a lighted match applied the result will be ordinary water. In the furnace the water passes into the atmosphere as vapor.

Whether burning coal or oil, the supply of air is of the utmost importance. If too much air is supplied, combustion will be complete, but much heat will be lost in heating the excess air which goes up the smoke pipe.

If not enough air is supplied combustion will be incomplete. The heat will not be generated, but will pass up the stack in the form of unconsumed carbon, or combustible gases.

Through long practical experience, engineers have found out how to make the most steam with coal.

The burning of oil is in reality a much simpler proposition than the burning of coal, as there is no grate and the question of the proper amount of air above or below the grate does not enter into the question.

But the following consideration apply equally to both coal and oil burning, and the engineer who has not given thought to the subject, will do well to do so.

The temperature of the gases passing up the smoke stack must be kept as low as possible. It has already been explained that the degree or intensity of heat, can be measured with a thermometer or pyrometer, and that the quantity of heat necessary to produce a certain temperature is measured in heat units. Consequently if the temperature of the gases of combustion, when passing up through the smoke stack is unduly high, it simply means that the heat units are passing up to heat the outside atmosphere, instead of going into the steam.

Smoke stack temperatures of 500° F or lower, are possible with properly designed, and properly handled boilers.

Complete combustion has already been explained. The presence of combustible gases at the base of the smoke stack even in very small quantities is a sign of incomplete combustion and consequent waste of fuel.

The particular combustible gas which shows that *combustion is incomplete* is *carbon monoxide* (C.O.). If the necessary air were supplied this gas would not form. An additional part of oxygen would form carbon dioxide, which indicates complete combustion. In order to know what is taking place in the boiler, some form of a gas analysis outfit is necessary.

Such outfits are now furnished by many manufacturers, and no explanation will be attempted here, other than the general principle upon which such outfits are operated. A well known apparatus is the "Orsat."

Sampling pipes are furnished by means of which an individual sample of the gas is sucked from among the boiler tubes, the uptake, the base of the smoke stack or even the furnace itself. The gas thus obtained is successively passed into the graduated bottles of the outfit containing chemicals which will absorb the gases.

The smoke stack gas will contain carbon dioxide, carbon monoxide, uncombined oxygen and nitrogen. The sample is passed into the first bottle containing a chemical which will absorb only the carbon dioxide, and accordingly the volume of the sample will be reduced by the amount of the carbon dioxide it contains. Thus the percentage of carbon dioxide is obtained. The percentage of carbon monoxide and oxygen are obtained similarly in other bottles containing chemicals which will absorb carbon monoxide and oxygen respectively.

Complete directions for the use of such outfits are furnished by the manufacturers, and such directions will be in detail and much clearer than any that could be given here.

The least fuel will be used when the air supplying is so regulated that the temperature is at *the maximum in the furnace* and a *minimum at the base of the smoke stack.* An insufficient air supply, causing imperfect combustion, cools the whole plant. An excess of air cools the furnace, and also tends to heat the base of the smoke stack.

It is impossible to regulate the air so that there will be just enough to insure perfect combustion, and no more. It is better to have too much than too little, and long experience has demonstrated that the best results are obtained when the gas analysis shows not more than ½ or 1% of carbon monoxide, between 2 and 3% of free oxygen and about 15% of carbon dioxide. The remaining 82% of the sample is nitrogen, and can be disregarded.

Other authorities believe that best results are obtained with a complete absence of carbon monoxide, and oxygen between 2 and 8%.

Air leaks in a boiler are a source of waste. To obtain the best results the air should be admitted to the furnace only through the ash pans, the furnace doors, or the air registers as the case may be.

In coal burners, the air supply above the grate (through the furnace doors) is small. The admission of cold air into the furnace, by opening the furnace doors wide will cause unequal strains and leaky tubes due to sudden contraction.

This trouble is avoided in oil burners, but it is more essential that the boiler casings, uptakers, etc., have no air leaks, as the proper and economical operation of an oil burner is absolutely dependent upon the regulation of the draft.

FUEL OILS

Crude, petroleum as it comes from the well, contains gases, gasolene, kerosene, gas oil, lubricating oil, fuel oil, water, salt and sand.

The first products are extracted in oil refineries, by the process of distillation. After distillation the remainder is allowed to settle in order to draw off the water, salt, and sand. The final product, Fuel Oil, is known as tapped crude oil or petroleum.

There are two classes of petroleum as it comes from the well: (1) one that distills down to a parrafin base. (2) one that distills down to a heavy black asphaltum base. Another base oil comes from Russia but we are not greatly concerned over it here.

The parrafin oils are found generally in the eastern part of the United States, while the asphalt oils are found in Texas, California and Mexico.

The parrafin, or eastern oils leave a small percentage of fuel oil, after distillation, while the asphalt oils leave a large percentage.

Some of the crude oils do not yield enough to pay for the process of refining, and are sold as fuel oil direct from the settling tanks.

The following tables serve as an approximate comparison between the best steaming coals and fuel oils.

Name	Carbon	Hydrogen	Oxygen	Sulphur	Nitrogen	Ash	B.T.U. per lb.
Pocahontas..........	84%	5%	4%	.7%	1.3%	5%	14600
Clearfield, Pa........	80%	5%	5%	.9%	1.4%	7.7%	13000
Cardiff, Wales.......	87%	5%	4.1%	1.4%	1%	4.9%	14500
Newcastle, Eng.......	82%	5.5%	6.5%	1.3%	1.6%	3%	14800
Pittsburgh Steaming..	76.5%	5.2%	8.1%	1.2%	1.4%	7.6%	13300

Name	Carbon	Hydrogen	Oxygen	Sulphur	Nitrogen	Heating Value B.T.U. per lb.
California Oil.........	87%	11.6%	.2%	.5%	.75%	19000
Louisiana Oil.........	86%	12.3%	.8%	.5%	.2%	18000
Mexican Residue.....	84%	12 %	.1%	3.8%	.5%	19000
Texas Co., Oil.........	86%	12.7%	.4%	.5%	.25%	18000
Gaviota California...	83%	11.5%	2.4%	2.5%	.6%	18000
Standard Oil Mexican.....	84%	11.6%	.6%	3.5%	.4%	19000

There are a great many fuel oils on the market having about the same chemical constituents, and about the same heating value.

The constituents of an oil have very little to do with its proper burning.

Sulphur is an objectionable constituent, as a proportion greater than 1% is liable to cause serious corrosion on the fire sides of the boilers. Oil containing more than ¾ of 1% of sulphur is not accepted in the Navy on that account and should not be elsewhere.

Free water and sediment in the oil which might clog or injure the burners or valves is the cause of most of the trouble that the engineers will experience.

It should not exceed 1%, and if water is found by test in greater quantities, it can usually be traced to an outside source.

Complete knowledge of a fuel oil can only be gained by a complete chemical analysis, which cannot be done on board ship.

The *specific gravity* of fuel oil, can be found by filtering a sample into a container, and allowing a hydrometer to float freely in it.

The hydrometer used for this purpose, has a scale graduated in degrees Beaume, and a temperature scale in degrees Fahrenheit.

Oils are rated in gravity in Beaume degrees of 60° F.

The specific gravities vary from 1.025 to .749, and are generally rated in degrees Beaume at a temperature of 60° F.

The specific gravity can be found from the following formula:

$$\text{Sp. g.} = \frac{140}{130 + \text{Degrees Beaume}}$$

$$\text{Beaume} = \frac{140}{\text{specific gravity}} - 130$$

Also the tables prepared by the Inspector of Petroleum of the New York Exchange Annex, gives the specific gravities of light oils for every 1/10 of a degree of the Beaume scale.

THE HEAT VALUE OF FUEL OIL

The heat value of a fuel oil cannot be determined exactly except with a calorimeter.

It can be determined approximately by the following formula, which are sufficiently accurate to obtain a very good idea of the fuel.

$$\text{B.T.U.} = 17680 + 60 \times \text{Baume reading}$$

or

$$\text{B.T.U.} = 18650 + 40 \times (\text{Baume} - 10).$$

THE FLASH POINT

The Flash Point is the temperature at which a heated oil will give off a vapor, which when mixed with air will form an explosive mixture.

Oils with a high flash point are safer than those with a low flash point.

A knowledge of the flash point of an oil is necessary as a consideration of the suitability and safety for use on board ship.

The exact test for the flash point is made with the Abel or Pensky Marten closed cup apparatus.

FIRE POINT

The fire point is the temperature at which the gases given off will burn steadily. This test may be made in an open tester. The fire point is always more than 25° F. and less than 50° F. greater than the flash point. Consequently an approximate idea of the flash point, may be obtained from the fire point.

SULPHUR CONTENTS

The Sulphur contents of an oil may be determined only by chemical analysis.

But if the percentage is above 1%, the oil will have a characteristic odor which is very perceptible. This in itself is sufficient for the Engineer to protest against its use.

VISCOSITY

Viscosity is a term applied to the degree of fluidity of the oil. It is an indication of the ease with which it may flow or be pumped. The lower the viscosity, the more easily it can be handled.

Both the viscosity and specific gravity of the oil fall with a rise of temperature.

Viscosity is measured by the rate of flow of a certain amount of oil at a certain temperature through a standard orifice.

There are a great many viscosometers, but the simplest, and one in most general use is Saybolts, in which 70 cubic centimeters of oil are put in the cup, 60 cubic centimeters allowed to run out, a stop watch timing the interval.

Heavy oils of a high viscosity require heating to handle readily.

All fuel oils have their least viscosity at a temperature of about 150° F.

A TEST FOR WATER AND SEDIMENT

A test can be made as follows: A sample of oil is mixed with an equal quantity of high grade gasolene. The mixture is thoroughly shaken, and 100 cubic centimeters is poured into a long glass tube graduated in hundredths and left to stand for six hours. The water and sediment will settle to the bottom, and the percentage can be read on the graduations. A percentage greater than 1% is very likely to cause trouble at the burners.

ADVANTAGES OF LIQUID FUEL

The heating value of one pound of fuel oil is approximately 1.4 times the heating value of a pound of coal.

A ton of coal occupies about 44 cubic feet of space and a ton of fueil oil occupies about 39 cubic feet.

Oil fuel can be carried in waste spaces, such as double bottoms, and isolated spaces, where coal cannot be carried.

Oil can be burned with better air and draft regulation than coal thereby giving a lower loss in the smoke stack gases.

There are no waste losses from oil, as with coal.

The boiler heating surface remain clean with oil.

Fewer men are required to handle fires consequently less men in the crew.

No expense for firing tools, ash buckets, ash engines, etc.

Less expense in the handling and stowage of oil, as compared with coal both at sea and in port.

Less time required to get up steam. Steam easily controlled.

Very little time required to fuel ship.

When properly handled less wear and tear on boilers.

OIL BURNING INSTALLATION

Oil in the mass is not readily combustible. To burn oil, it must be mixed with oxygen and as air contains oxygen, air is therefore forced into the furnace and mixed with the oil in order that it may burn. Oil which is not mixed with the proper amount of air will not burn properly and it is for this reason that the draft in the furnace is so important. If the gases within the furnace do not receive the proper amounts of oxygen to support combustion, incomplete burning is the result and the heat of the fuel which should be imparted to the water within the boiler, passes up the stack instead, in the form of unburnt gases.

About 200 cubic ft. of air or rather the oxygen contained in 200 cubic ft. of air, is necessary to burn one pound of oil. To secure the proper mixture of the air and oil it is necessary to spray the oil in the furnace in the form of fog. The process of breaking up the oil in the fog or spray is called *atomization.*

There are three methods of atomization. They are, atomization by compressed air, by steam and by mechanical means. Atomization by compressed air is noisy and expensive and requires external atomization fittings. There are therefore some objections to its use. Atomization by steam has given good results in shore plants where the loss of fresh water is not a matter of great importance. One objection to the steam method is that a certain amount of water is mixed with the oil which may cause trouble. When a jet of live steam is employed to atomize fuel oil, ordinary good practice requires that at least 4% of the total steam generated be so used. This, besides being a waste of power, represents a loss of fresh water, a very important factor in marine practice. The mechanical means of atomization is the more favored for use in the Merchant Marine.

There are two types of burners, using the air or steam as the atomizing agent: (1) outside mixing, and (2) inside mixing. In the outside mixing type of burner, the oil dribbles into the blast of steam or air, and is atomized in much the same manner that medicine is atomized in a throat sprayer.

In the inside mixing type, the oil and air or steam mixed within the burner, and passing out of the nozzle as a mixture, where the oil is atomized as the result of the expansion of the air or steam.

MECHANICAL ATOMIZATION

The mechanical type of burner atomizes and sprays the oil into the furnace by means of pressure alone, without the use of compressed air or steam.

Atomization is accomplished in two ways: (1) By forcing the oil through a twisted spiral passage like the thread of the screw, and (2) by forcing the oil tangentically into a circular oil chamber, in the center of which is a small central orifice, through which the oil is sprayed through the burner tip.

The oil in passing through the twisted passage has its particles severely jarred and issues from the burner tip in the form of small hollow cones. The same conditions apply to the tangentical method of mechanical atomization.

Many persons imagine that the oil issues from the burner tip in the form of whirling spray, it is not so. It issues in straight lines in the form of the conical spray and at various angles up to 90 degrees depending upon the design of the burner. The whirling motion of the oil is entirely within the burner, and within the oil chamber proper.

A poorly designed burner may fail to break up the particles of oil sufficiently, and in this case they will fall to the bottom of the furnace by reason of their weight, before combining with

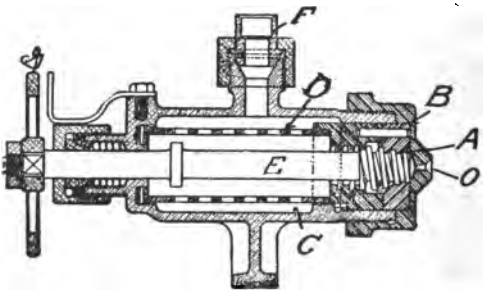

Fig. 1

air. When enough oil collects on the bottom, the explosion of the gases given off would cause back flare.

Fig. 1 shows a Thornycroft Burner of the first type.

It consists of the tip B, the atomizer head A, the burner chamber, C, the inner perforated casing D, and the valve stem E, which is fitted with a tapered thread which engages loosely with a similar tapered thread in the atomizer head A. The oil enters the outer chamber through the opening F, passes through the strainers casing D into the inner chamber, and follows the tapered thread on the valve stem and leaves the burner through the opening O. The opening O is regulated by a needle valve on the end of the valve stem, operated by the hand wheel G.

Schutte-Koerting Burner. Manufactured by the Schutte & Koerting Company of Philadelphia. This burner is shown in detail, together with the method of admitting air for combustion, as applied to the Babcock & Wilcox boilers of the U. S. Torpedo Boat Tender "Melville." Figure 2. A method of attaching the burner to a Scotch-boiler furnace is shown in Figure 3. This burner is one which depends upon forcing the oil through the helical channels formed by the thread of a screw in order to give it the necessary whirling motion. This principle was used in the early type of Koerting burner and is still retained. Very considerable designing skill has been shown in the method of attaching, arrangement of strainers, etc. The small spindle on which the thread is cut is faced at the end and

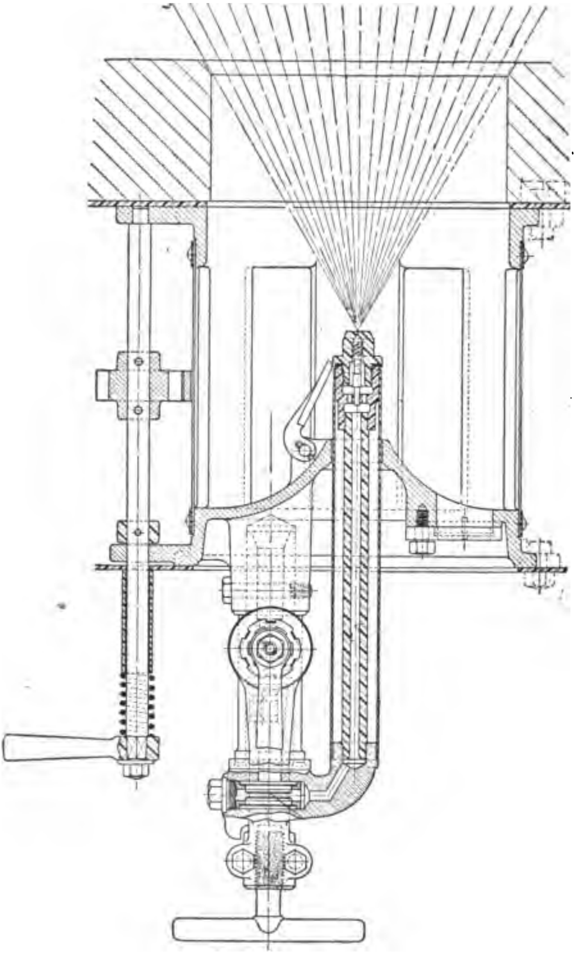

Fig. 2

Schutte & Koerting Burner and Air Control as Fitted to Babcock & Wilcox Boilers of the U. S. S. "Melville" rests in a steep tip adapted to receive it; a central hole in the body of this tip is counter-bored to give a conical chamber at the end of the thread, and this chamber communicates with the outlet orifice; the oil is therefore forced into the small conical chamber with the rotary motion due to the action of the thread. The end of the spindle opposite the helical thread is squared in section and fits into a square hole in the nozzle of the burner, which prevents the spindle from rotating when in operation.

The air admission chamber is cylindrical in shape and is provided with longitudinal openings parallel with the axis of the burner, which admit the air for combustion. These openings are covered by an adjustable sheet-iron cylinder, which fits on the outside, and the air is controlled by rotating this cover. The air is not given a whirling motion. In order to obtain the best mixtures and prevent pulsations, a high air pressure is usually carried and the air forced through restricted openings at high velocity.

Fig. 4 shows the Fore River Burner, a type of the tangential spray. It consists of the tip B which is screwed into the atomizer head A. The atomizer head A is screwed into burner casing C. The atomizer head has a rear threaded portion, through which the threaded valve stem D extends. The valve stem D has a needle valve extending into the tip B to regulate the opening at O. The valve stem is operated by a hand wheel or wrench on the square end F. The oil enters through the opening E and strainer G, and passes through the openings in the atomzier head,

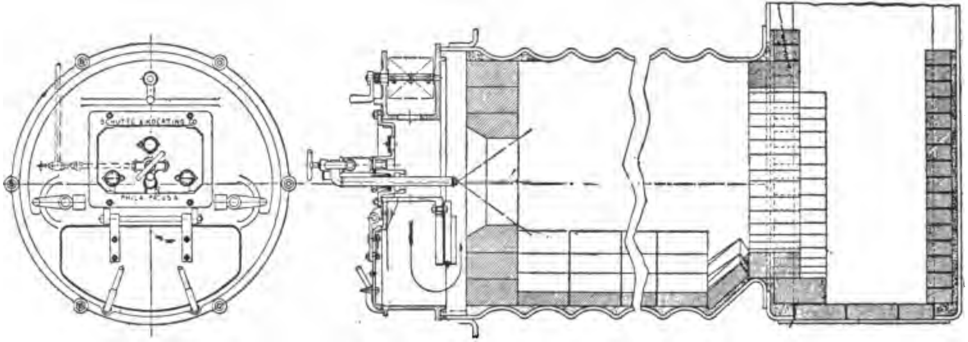

Fig. 3
Schutte & Koerting Burner Fitted to Scotch Boiler.

as shown by the arrows into the space around the inner end of the tip B. The tip B has two holes extending tangentially from this space to the space at the opening O. The arrangement of these holes is best seen in the end view (b).

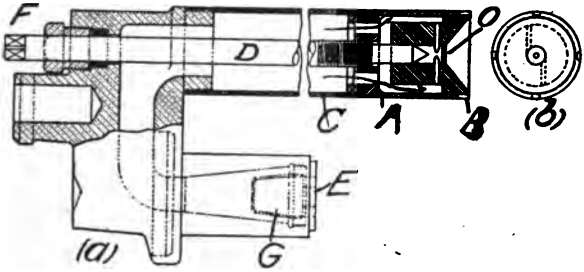

FIG. 4
Fore River Burner

The B. & W. burner formerly known as the Peabody (Fig. 5) is the same in principle as the Fore River Burner, the main difference being that there are four tangential holes, instead of two, as shown in the end view B (Fig. 4.)

The tip B screws on the atomizer head A, which in turn screws on the casing C, as shown. The oil enters at E, its admission to the casing C being controlled by the valve stem D, operated by the hand wheel F.

The White Burner. Manufactured in sizes from 25 to 175 boiler horse-power. The burner is of simple but rigid construction and is designed to atomize the oil, preheated to the point of fluidity, which by pressure is driven along flutes or grooves cut at an angle on the surface of the cone (C). These grooves give the oil a

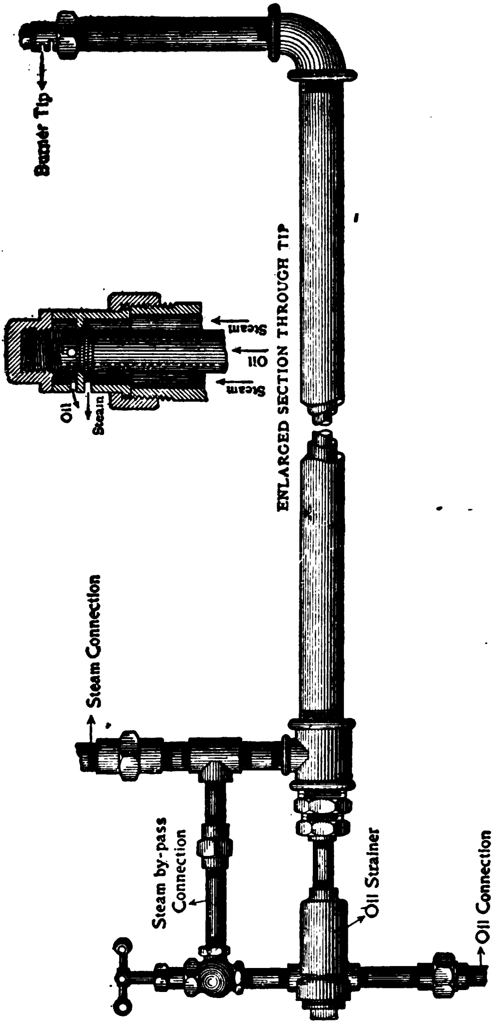

FIG. 5
B. & W. Oil Burner—No. 1

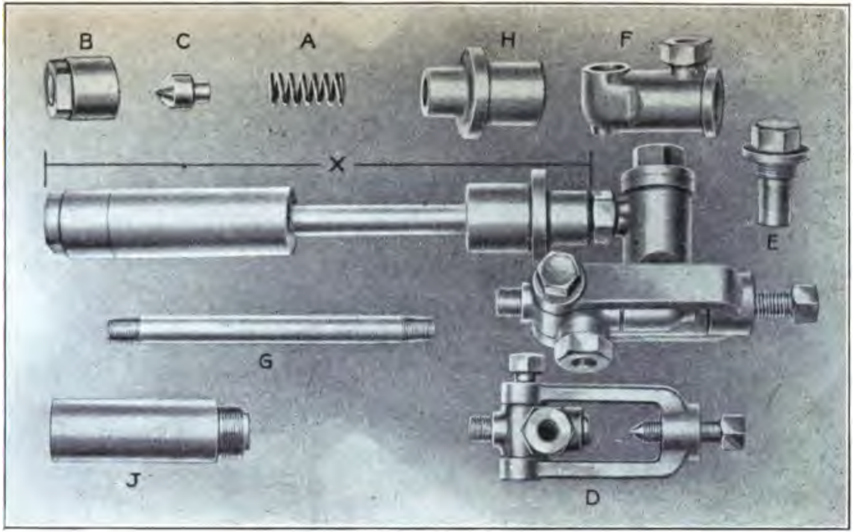

FIG. 6. White Burner

A—*Spring*
B—*Tip*
C—*Fluted Cone*
D—*Quick Detachable Union*
E—*Strainer Basket*
F—*Strainer Body*
G—*Burner Tube*
H—*Burner Bushing*
J—*Burner Body*

whirling motion as it impinges upon the burner-tip (B) and is forced through the small hole, forming the whirling cone of very fine spray. The average operating oil pressure is 80 pounds, but this may be lowered to 10 pounds and the spray will be still sufficiently fine to easily ignite.

There are no moving parts to the burner. The cone (C) is held properly seated by the pressure of the spring (A). The hole in the tip (B) through which the oil spray issues, is graduated to thousandths of an inch in diameter, ranging from 42/1000 to 70/1000 in ordinary practice.

All tips are interchangeable and may be readily removed for cleaning. The burner itself is removed from the furnace front in less than thirty seconds. By disconnecting the oil feed line—quick detachable union (D)—it may be withdrawn by hand and a spare burner carrying a clean tip inserted in its place.

There is an oil strainer (E) of fine mesh, located in the head of the burner to arrest any particles of grit that might lodge in the hole in the tip. This strainer-basket may be taken out and cleaned without removing the burner.

The burner is surrounded by a jacket tube on which operates a sliding cone to govern the location and spread of the flame. There is a further arrangement of air-regulating cones which controls the air admission, insuring an intimate and thorough mixture of air and oil.

The Todd Mechanical Oil Burner and Air Control. Capacity 100 to 1600 lbs. oil per hour. This construction has been designed to permit an exceptionally large range of adjustment of the air

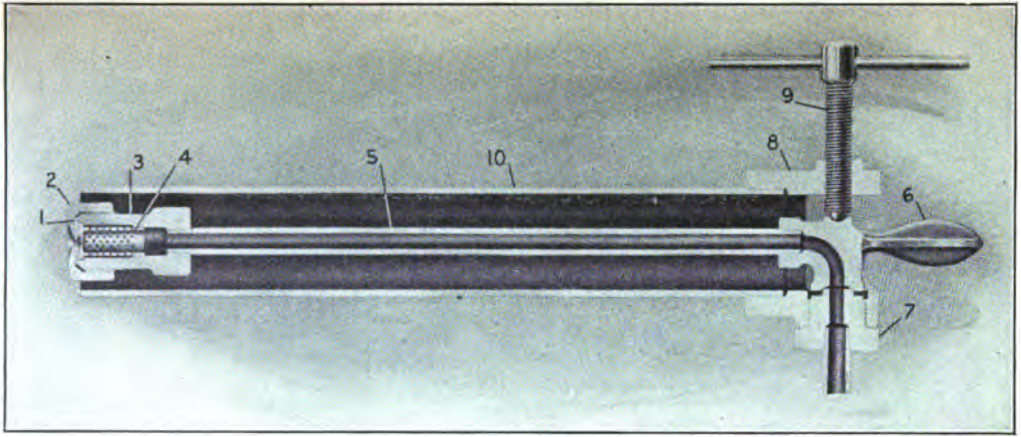

FIG. 7

Sectional View of Todd Oil Burner

1. Tip.
2. Nut.
3. Body.
4. Strainer and Atomizer.
5. Tube.
6. Handle.
7. Union Bushing.
8. Housing.
9. Housing Screw.
10. Jacket Tube.

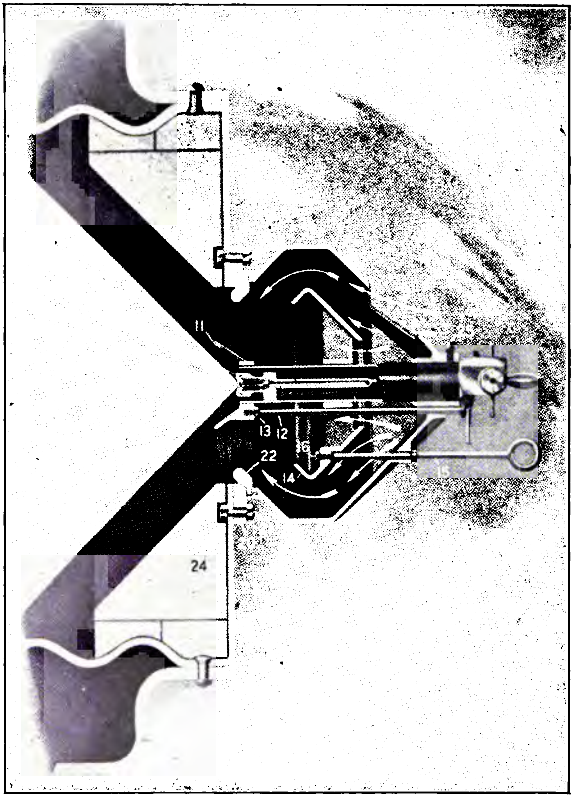

FIG. 7A

Sectional View of Todd Oil Burner on Scotch Boiler

PARTS

11. Flame Cone.
12. Flame Cone Rod.
13. Flame Cone Nut.
14. Air Cone.
15. Air Cone Rod.
16. Air Cone Rod Nut.
17. Air Register.
20. Air Registered Hinged Plate.
21. Air Registered Hinged Plate Bolt.
22. Venturi.
23. Furnace Plate.
24. Brick Venturi.
25. Jacket Tube Set Screw.

and oil control as well as the elimination of direct radiation into the stoke hold. It effects complete diffusion of all air entering the furnace, equalizes the pressure and eliminates currents around and to fires.

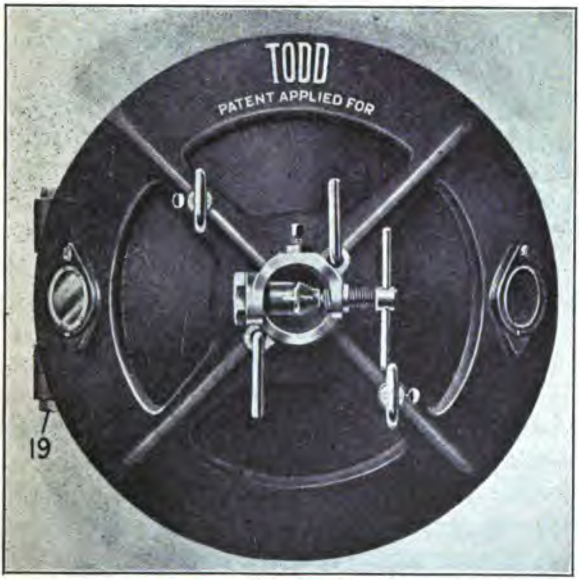

FIG. 8
Outside View of Todd Oil Burner

The air cone adjustment maintains a uniform velocity of air entering the fire irrespective of volume or size of fire. This adjustment can be varied at each burner to compensate for the varying air supply due to the position of ventilators or other air supply.

The burner length is adjustable and its location with reference to the air venturi ring can be varied to suit any reasonable requirements without changing burner length.

The burner tip with the combined atomizer and strainer are assembled as a unit. Their construction prevents improper assembly and they are readily accessible for cleaning or renewal.

All the parts used in the construction are standardized and interchangeable.

The complete front is hinged on a ring plate which is bolted to the furnace front. This gives access to the furnace and also the burner assembly which is swung out with the front when it is opened.

The burner connection to oil supply manifold is flexible and will stand pressure of 1000 pounds per square inch. This feature eliminates the dangers of rigid piping and the leaky connections caused by constant making up of joints.

The installation of the front on a boiler or furnace requires no special tools or fittings.

The Fisher Burner. The Fisher Burner introduces a feature which is entirely new in the oil burning art, and the development work now being carried on by the Peabody Engineering Corporation in conjunction with the Navy Department, indicates that the Fisher burner will be capable of very great range in individual burner capacity. It is true that where a large number of burners are used on a single boiler any desired range in boiler capacity may be secured by cutting a greater or less number of burners out of service, and by the substitution of small tips when minimum capacities are desired. On the other hand, it is often desirable to keep all the burners in service at reduced rates, thus maintaining an even distribution of heat throughout the furnace and eliminating the necessity of changing the burner tips; furthermore, this system lends itself very favorably to automatic control, which will doubtless be one of the developments of the immediate future.

Commander Joseph O. Fisher, U. S. N., being familiar with the use of mechanical atomizers for boiler purposes, conceived the idea of adapting the principle of these atomizers to the injection of oil into the cylinders of the internal combustion engine; the plan being to alternately open and close the orifice of the atomizer to correspond with the strokes of the engine. Finding that the frequent and intermittent opening and closing of the valve interrupted the flow of the oil through the tangential passages of the tip to such an extent that the whirling action and spraying effect was entirely destroyed, he hit upon the novel idea of providing the central chamber with a secondary outlet, so that a constant flow was secured through the central chamber of the tip, whether the valve was open or closed. In all other mechanical atomizers, all oil which enters the central chamber through the tangential passages, finds an outlet through the orifice of the tip and the amount of oil delivered depends only on the size of the orifice, the size of the tangential ducts and the oil pressure, with the consequent limitation in range of capacity of the burner already referred to. In the Fisher burner the maximum amount of oil may be admitted to the central chamber at all times, thus maintaining the whirling motion undiminished, while if desired, only a portion of the oil may be allowed to pass through the orifice into the furnace or into the engine cylinder, the remainder of the oil being by-passed through the secondary outlet back to the pump suction or storage tank.

It will be obvious that this feature provides at once a ready means for controlling the capacity of the burner and for reducing same to a very low percentage of the maximum, while at the same time maintaining the whirling effect of the oil in the chamber of the tip undiminished. It has actually been found that a better spray may be produced at the lower capacities than at full load,—just the opposite of the action of the usual form of mechanical burner. The Fisher burner is illustrated in Fig. 9.

The Coen Burner and air control is illustrated in Figure 10. The burner is of the type which varies the output of oil by altering the size of the small tangential channels which deliver the oil to the central chamber. The main air admission, as is clearly shown in the illustration, is controlled by an adjustable disc, while a supplementary air supply enters through the side of the cylinderical chamber in which the burner is placed, and which is controlled by a sliding cylinder. An adjustable disc or plate prevents direct impact of the air at the point where the spray leaves the tip.

There are various other mechanical burners in use, but their principles are generally the same, the differences being in the details of assembly

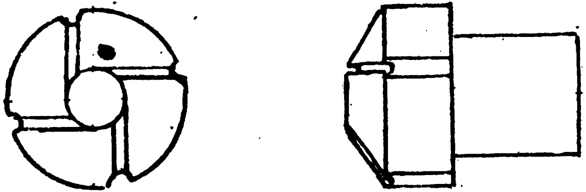

FIG. 9
Fisher Burner used in U. S. Navy
Courtesy Navy Department

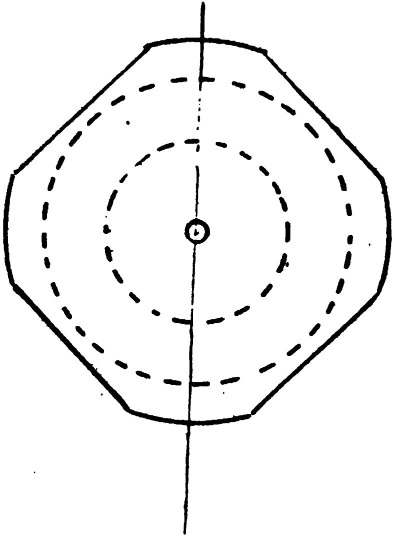

FIG 9A

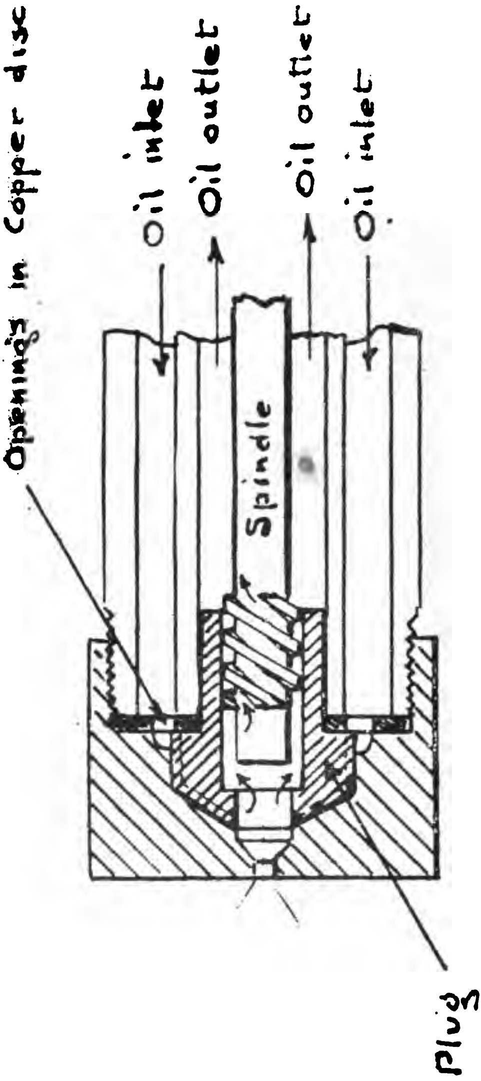
Openings in Copper disc
Oil inlet
Oil outlet
Oil outlet
Oil inlet
Spindle
Plug

FIG. 9B

and control of the supply of oil. The angle of the conical spray differs with the different types of burners. The best spray angles are between 60 and 70 degrees.

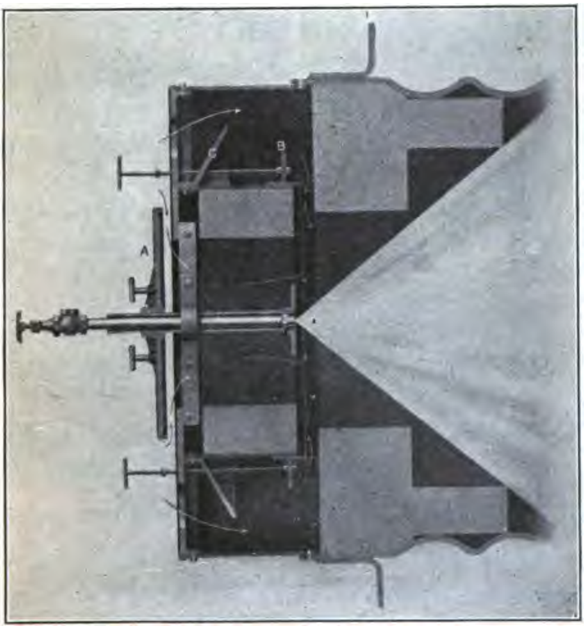

FIG. 10
Coen Burner and Air Control

Experience with different types of burners has demonstrated that, a valve as part of the burner to control the supply of oil by throttling is undesirable.

It is necessary that each burner spray the same amount of oil into the furnace. This can be accomplished only by having the outlet orifices in the burner tips of exactly the same size, and operating them wide open under a constant oil pressure. This is very necessary in connection with the proper regulation of the air supply.

The simpler the construction of the burner, the more hard usage it can stand, and the easier it can be cared for.

Oil is usually supplied at a pressure of about 200 lbs. The fires should be regulated by the number of burners in use, in preference to the regulation of the amount of oil at each burner.

The Viscosity of an oil is the main point to consider in connection with proper atomization for burning.

Repeated tests have shown that in order to have good atomization and complete (smokeless) combustion, the viscosity must be reduced by heating to about 320 Saybolt.

Heating further does not improve matters, and may even prove a detriment. Heating above the flash point is dangerous.

The capacity of a burner is increased by heating the oil up to a certain point, called the critical point. When this point is reached additional heating lowers the capacity.

THE SYSTEM

Fuel oil is generally carried in special tanks or double bottoms. Each oil tank has a suction pipe leading to the oil supply pump. In most oil burning vessels settling tanks are installed. These tanks usually have a capacity of about one day's supply. The oil supply pump pumps the oil from the special storage tanks to the settling tanks, or it may be used to pump oil from one storage tank to another.

The settling tanks are sometimes located overhead in the engine room angles. All tanks are fitted, or should be fitted, with steam lines to extinguish fire and to steam out the tanks.

The oil service pumps which pump the oil to the burners take their suctions direct from the settling tanks. A short suction is most desirable. There is also a connection so that a suction can be taken direct from the storage tanks in case of necessity. The settling tanks are fitted with gage glasses, drains, drain valves, and air escapes. Steam heating coils are also fitted in these tanks. Heating the oil in the settling tanks aids in separating the water and sediment, which can be run off through the bottom drain valves.

DUPLEX BASKET STRAINERS

These strainers are installed in manifolds in the suctions for the oil service pumps, and also in the discharge lines to the pressure oil heaters.

Similar strainers are fitted in the suction and discharge lines of the oil supply pumps.

These strainers are usually of the twin basket type, and are so arranged that one strainer can be and by-passed, and the basket removed and cleaned while the other is in use.

The frequency of cleaning of strainers depends on the working conditions, and largely upon the amount of sediment, etc., contained in the fuel. About twice a day is usually sufficient.

OIL PIPING

Oil piping is made of steel with steel flanges. All joints and fittings should be made with metal to metal joints. But frequently an oil joint cannot be made tight without a gasket in which case a gasket made of oil paper, or a coat of shellac, will give the most satisfaction.

Particular attention should be given to the tightness of all oil lines and joints. All oil lines should be frequently tested cold to a pressure of 50% higher than the working pressure, and carefully examined for leaks. Oil leaks are a source of danger, and if your life is not valuable to you, remember that the oil lost through a small leak is valuable to your owner.

PUMPS

The oil supply pumps, and the oil service pumps are usually of the duplex plunger type.

In order to insure a good suction, the suction sides are fitted with large vacuum chambers.

One necessary condition for burning oil successfully is to have a steady pressure which will give a steady discharge of oil at the burners without any fluctuations. This is accomplished by large air chambers on the discharge sides of the oil service pumps, and sometimes by additional air chambers on the oil lines on the dead ends.

The expansive effect of the air contained in the air chamber prevents the fluctuations of pressure which momentarily occurs at the end of the stroke which can be noticed especially in a slow speed pump. These air chambers should be charged with air at about 100 lbs. pressure before the pumps are started or the air valves opened. Heated oil absorbs the oxygen from this air and it is necessary to recharge the chambers as soon as there is any sign of fluctuation at the burners (usually about twice a day).

Several patent rotating plunger pumps are now in the market, which are designed to give a uniform pressure without the air chambers. Although it is said that they accomplish the purpose very well, the air chamber is in general use, and from all indications will not be discarded soon.

OIL HEATERS

Oil heaters are usually located in the fire rooms, on the discharge side of the oil service pumps. They are so arranged that they can be by-passed if desirable. The oil is heated in passing through them.

There are several different types. They differ somewhat in the details of construction, but conform in design and principle to high pressure feed water heaters.

The Schutte-Koerting is a type that is extensively used. It consists essentially of two corrugated copper tubes one inside of the other, the whole being enclosed in a steel shell. The oil is circulated in the corrugated space between the copper tubes, the ends of the space being connected in series with the oil line. Steam enters at the upper end of the shell, and passes through the inside of the inner copper tube and around the outside of the outside copper tube. The condensate is trapped off from the bottom of the shell.

Fig. 11 shows the general arrangement. A thin film of oil is forced between the corrugated pipes which can be heated to any desired temperature but not to exceed the temperature of the steam.

The steam coil in the settling tank also discharges to a trap. These traps are provided with gage glasses and fittings, by which the condensed water may be drawn off and examined for oil.

Oil leaks in the heaters should be carefully guarded against. It is very rare that the steam pressure in the heater exceeds the oil pressure, consequently leaking oil will find its way into the traps which discharge into the feed tanks. The effect of oil in the feed water, if allowed to continue for an appreciable length of time will cause *serious damage to the boilers.* Watch the tank into which the traps drain very closely for the presence of oil.

The heating coils in the settling tanks are there simply to reduce the viscosity of the oil enough to insure that the oil service pump suction will not fail.

When oil burning was in its infancy, it was supposed that heating the oil to as high a degree as possible in the oil heaters would result in increased economy in the same way that heating the boiler feed water in feed heaters does. Undoubtedly there is a slight economy, but the gain is offset by the practical consideration of the reduction in burner capacity which occurs when

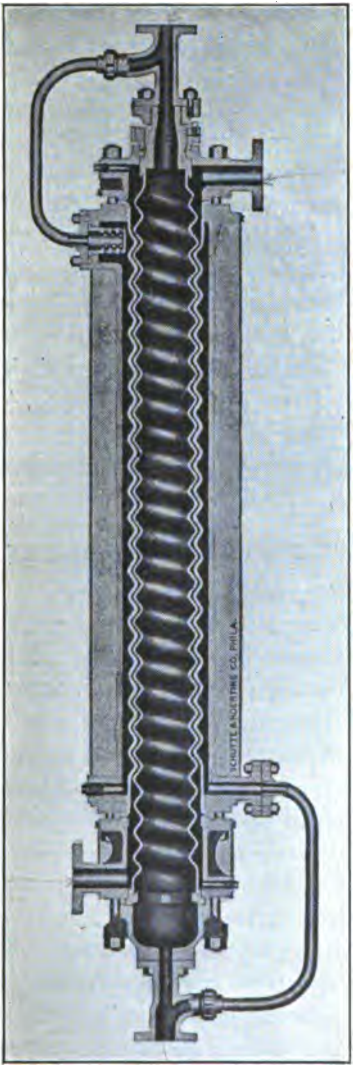

Fig. 11
Film Oil Heater
(Schutte & Koerting Co.)

the oil is heated above 150° F. The good effect of heating is that it makes proper atomization possible.

OIL LINES

Each boiler has its individual oil line, branching from the main line, which is controlled by a master valve. Each burner has its individual valve so that it may be cut in or out as desired. In most installations the delivery line returns to the heater, which will permit of circulating the oil through the heater, for the purpose of heating the oil when the fires are first lighted.

A hand pump is also supplied for starting when there is no steam available all boilers being cold.

AIR REGISTERS, CONES, OR TUYERES

The proper regulation of the draft is of as much importance in oil burning as atomization. It has been stated previously that about 200 cubic feet of air are required to burn one pound of oil, and if the air supply is too great or too small waste will result. With good atomization, it is absolutely necessary that the air mix thoroughly with the oil in order that each individual atom shall burn. Complete mixture of air and oil is provided for by having the air enter at a fairly high velocity.

If the air does not thoroughly mix with the atomized oil, irregular combustion takes place, and the boiler *vibrates or pants.* This *panting* is very hard on the boilers, and if allowed to continue long, will shake down the brick work, and rack and loosen joints in the boiler casing, and boiler connections.

Therefore no air should enter a boiler except through the air registers or cones. All joints and seams of the boiler casing should be made airtight with asbestor wicking or plastic magnesia. If a forced draft system is installed the boiler casings of water tube boilers may be tested for tightness by bringing a naked light into close proximity with suspected leaks while the blowers are running. The leaking air will suck in or blow out the flame according to the system of forced draft. Some of the air leaks can be detected when the boiler is under steam by the glow of fire through the seams.

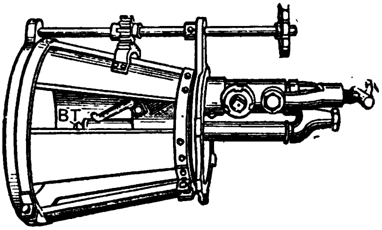

FIG. 12

An Air Register consists of a rotating coned sleeve, working on the outside of another cone, which is operated by a rack and a pinion. Fig. 12 shows such a register of the Schutte-Koerting type, with a Schutte-Koerting burner.

Boilers of the water tube type like the Babcock and Wilcox have an air casing over the furnace front. The rear end of the air register butts against the outer plate of the air casing, with the mechanism and valves of the register and burner

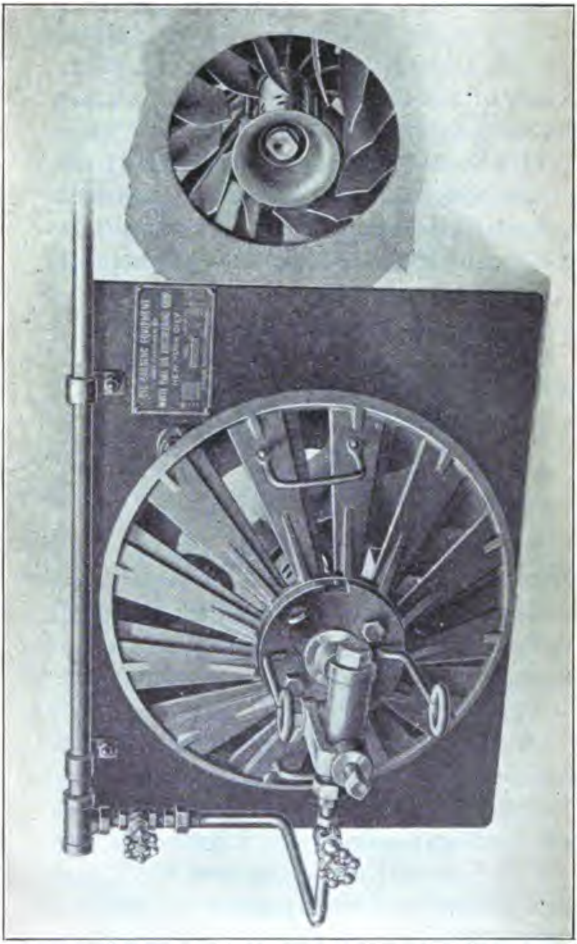

Fig. 13

External and Internal Views of Air Register and Burner extending into the fire room within easy reach. The front end of the register and the burner tip are about even with the boiler casing. The air comes through the air doors, and enters the furnace past the burner tip through the slots in the register and by varying the width of the slots in the register, the velocity of the entering air is controlled.

The best system of forced draft for oil burning is the closed fire room system. The fire rooms are always cool, and both the quantity and velocity of the air can be controlled very nicely. By speeding up the blowers the fire room pressure is increased, and by reducing the air register opening, the velocity is increased without reducing the volume.

The type of register shown in Fig. 12 is simply an air distributor. Later designs have vanes in the register fixed at an angle for the purpose of imparting a whirling motion to the air as it passes the burner tips and mixes with the oil spray.

Peabody impeller plates have the vanes set at an angle of 45 degrees. The impellers are fixed, and the air supply is regulated by draft doors.

With the burners and registers as described, forced draft, with a fairly high air pressure, must be employed for the best results. The Howden hot air system can be employed with good results, but is more complicated than the closed fire room system.

When *natural draft* is desired the air register must be capable of admitting sufficient air for complete combustion at a low velocity. In order to insure a thorough mixture of the oil and air, the spray angle at the burner tip must be made wider.

It is necessary for economy that the entering air be as warm as possible. On *scotch boilers* this is accomplished as follows:

A space corresponding to the air casing space is formed on each furnace front. The burner projects through the center of this space into the furnace. A series of vanes are fitted in this air space, which are kept hot by the heat of the furnace front. The air for combustion is heated in passing these vanes. A sliding cone is fitted around the burner tip which regulates the mixture of air and oil spray, while an outer cone regulates the amount of air admitted past the burner.

This description fits an installation for oil burning, natural draft, with mechanical atomization.

Steam atomization is the best and safest method of burning oil with natural draft, and on this account will probably be continued in spite of the fact that the steam used to atomize amounts to about 4% of the total evaporation.

The safety of any forced draft system lies in the fact that the air pressure will not let fire or steam escape into the fire room. In steam atomization, the steam jet accomplishes the same purpose, but to a minor degree. Although the flash point of the average oil is in the lower hundreds, the burning temperature of the gases of combustion given off by the oil is in the thousands. It is therefore necessary to conserve the heat within the furnace and build it up until these high temperatures are reached. This is done by lining the furnace walls with fire brick and placing baffles so that the flow of hot gases will be checked and their heat imparted to the water within the boiler. That the right kind of fire brick is laid is of great importance as the high temperatures within the furnace will fuse brick of poor quality. It is also important that the casing be absolutely tight so that no air can enter except through the furnace fronts.

Furnace brick for oil burning must be of a superior quality. Unless the brick will stand a temperature of about 3300° F. without fusing or crumbling they will be of little use. When a brick drops out of the casing of a water tube boiler there is danger of burning a hole through the casing unless the boiler is shut down. The use of the brick for a lining is necessary to keep the temperature of the furnace at a high point to aid in complete combustion.

All of the furnace wall bricks should be secured to the casing by bolts, as otherwise vibration or panting will shake them down. The bolt heads must be protected from the intense heat with high temperature cement.

A number of high temperature cements for laying and repairing broken brick are now on the market. In laying brick such a cement should be laid on to cover the entire top of the brick. When two bricks are pressed together the cement which is squeezed out should not be trowelled to make a smooth wall, but should be beaded so that the thickest part of the cement covers the joint between the brick. This protects the edges of the brick from direct impact with the flame and when done properly will weld to the bricks and protect them where they would be most likely to crumble otherwise.

A brick wash made of the same kind of high temperature cement, made thin enough by the addition of water to be applied with a brush, should be applied to the bricks whenever it appears that they are exposed to the direct action of the fire. After continued use of such a wash the walls will become hard and flint like, and will last a number of years under normal conditions, provided vibration is not allowed.

The foregoing applies to the brick work of water tube boilers. The brick work of a scotch boiler is a fairly simple matter, except that the arching of the brick over the front end of the furnace and at the combustion chamber opening requires a considerable degree of skill. Such arch must be locked with a key brick. Bolts are not used. But the precautions in regard to beading the cement, and the application of a brick wash are as important in a scotch boiler as in a water tube boiler.

OPERATION OF AN OIL BURNING INSTALLATION

It is impracticable to describe in detail every installation to which the following directions are applicable. The reader must make such exceptions or additions, that good judgment or the peculiarities of his own situation may dictate.

TO START FIRES—COLD BOILERS

Provide a five gallon can of fuel oil. Connect the hand pump to the discharge end of the burner line, and take the suction from the five-gallon *can*. Several reliable hand pumps for this purpose are now on the market. Open all of the air registers wide to give as much air pressure as possible to the boiler. If dampers are fitted see that they are opened wide. Start the hand pump and bring the pressure up to 200 lbs., and maintain this pressure as steadily as possible. Dip the torch, which consists of an iron rod about four feet long, with a ball of waste or asbestos wicking, into kerosene. Light the torch and hold it close in front of the center burner tip, and turn on the oil valve. In cold weather, or with an oil of high viscosity, it may be necessary to hold the lighted torch in front of the burner until steam forms on the boiler. Ordinarily the oil will ignite readily, but the burner must be watched, and relighted if it goes out. Special care must be taken not to allow the oil to spray into the furnace if the burner goes out. As soon as the steam pressure has reached 75 lbs. or sufficient to handle the pumps, start the auxiliary condensor, and turn steam on the feed pump, the oil service pump and the oil heaters. As soon as these are running disconnect the hand pump. Next start the blowers, and close the air register vanes of burners not yet lighted. Regulate the air admission of the lighted burner, remembering that a large excess of air is necessary to prevent smoke until the brick work is good and hot.

Next cut in additional burners, but before attempting to light one, see that the register vanes are *wide open.* After lighting a burner, regulate the register to suit the conditions. If a burner goes out shut off the oil supply to that burner *immediately.* If any oil has sprayed into the furnace and collected on the furnace floor it will give off an explosive vapor which will cause a flare back. Open the air register wide and allow such vapor to escape before lighting the burner again.

The engineer can tell when the air is properly regulated with the gas analysis outfit, as previously described. Lacking this outfit, he can obtain a fair idea from the color of the smoke. *No smoke or white smoke* indicates an excess of air.

Black smoke indicates incomplete combustion, i. e., not enough air.

A *light brownish gray smoke* indicates that the air is about correct.

PRACTICAL DESCRIPTION OF ACTION WITHIN THE FURNACE

Now that the various fundamentals and auxiliaries of the oil burning system have been described, an endeavor will be made to give a simple and short description of what takes place within the furnace. Although short, none of the necessary accuracy in an article of this kind will be sacrificed. It is believed that the average handler of oil burning installations will find such a short description more useful than a detailed one of the various combinations of gases, constituents, gravities, etc. The above explanation is offered so that in case any reader has studied the subject before and encountered material filled with chemical analysis, tables, etc., he will not consider this article inaccurate because of the lack of them.

Therefore, from the standpoint of a man on the fireroom floor plates, when the oil is shot into the furnace in the form of a spray from the burner tip, the conditions that take place are as follows:

The air registers or vanes being adjusted to satisfaction, the oxygen of the air is able to mingle with the spray of oil when shot into the furnace. On starting up, the torch being applied heats the small particles of the spray of oil and when the flash point is reached, the gases given off take fire. The torch being still applied, the oil is heated to the fire point and the gases are enabled to support combustion, provided the temperature is kept up. In a fire just lighted it is sometimes necessary to keep the torch applied for some little time. In a fire burning for some time, the heat of the furnace and the fire itself heats up the incoming oil to the proper fire point so that burning is continued. It must be remembered that the oil on starting (except when the entire plant is cold) is first heated in the fuel heater in order that its viscosity may be reduced so that it may be pumped.

That the proper amount of oxygen (neither too much nor too little) is supplied within the furnace is of extreme importance. The three ingredients of fuel oil that must be considered in combustion are hydrogen, carbon and sulphur. A glance at the various tables of the composition of fuel oil will show that in the general make-up of the oils, the proportion of carbon runs to about 84%, hydrogen 12%, and sulphur in the neighborhood of 1%. Nitrogen, oxygen, water and sediment form the rest of the total. These figures, while rough, will serve to give some idea of the make-up.

The water contents of the oil are very small. This means the water contents as determined by the chemical analysis of the pure bulk oil. Many engineers, remembering the trouble they have experienced with water in the oil, would doubt the correctness of the statement were not this explanation offered. Water found in oil can always be traced to outside sources.

If the proper amount of air is furnished, the gases given off by the oil during combustion will be completely consumed and the remainder, a gas called carbon dioxide, will pass up to the stack. If the air supply is insufficient the gases will not receive their proper amount of oxygen and will pass up to the stack unburned with their heat units contained within them. The action is that the hydrogen being a fierce burner of itself, absorbs all or most all of the small supply of oxygen, leaving none for the combustion of the carbon and sulphur. And as the carbon forms the greater part of the gases of combustion; it forms smoke more or less dense and also deposits soot within the boiler. So that with insufficient air supply only a part of the available B.T.U.'s are liberated. Perhaps only 5,000 of the 19,000 heat units in a pound of fuel oil would be liberated under such conditions. The loss is apparent.

The color of the flame will indicate a good deal to the trained eye. If the flame is a pure intense white, with a sort of gaseous vapor hanging over it through which the boiler walls can be seen, there is too much air within. A dark, dirty, rather yellowish red flame is a sign of not enough air. This sort of flame may often be seen issuing from the stacks of plants throughout the countryside. A yellowish-white flame shows good combustion conditions are being obtained.

Nitrogen does not support combustion and acts to reduce the temperature within the furnace as it absorbs heat in passing through to the stack.

The amount of heat that is gained from the burning of the sulphur is so small that it is neglected in ordinary calculations.

If the temperature within the furnace is too low it will also cause poor combustion and form smoke.

FUNDAMENTAL FACTS

In a pound of fuel oil there are about 19,000 B.T.U.'s of heat value. This means that there is available for use in heating the water within the boiler just so many standard units of heat. It is therefore apparent that ideal conditions of combustion are present when all the available heat units are liberated within the furnace. And it is for this purpose that the boiler is so carefully designed, as heat units which are not absorbed by the water within the boiler and made to perform work within the engine, are lost, so far as the making of steam is concerned.

Suppose for purposes of illustration that the tubes were covered with dirt and soot or that the baffles were improperly placed. In the former case a certain number of the available heat units liberated by combustion would be used in overcoming the resistance of the soot and dirt before reaching the water. And this heat would have to be replaced by *more* in the shape of *more fuel.*

In the latter case with improperly placed baffles the heat of the hot gases would not all be absorbed by the water within the boiler as the gases would not be retarded sufficiently in their path through the boiler. Also it would require more heat to keep up the temperature of the furnace and this again comes back to the fuel pile.

A pound of coal has only about 14,000 B.T.U.s available for liberation by combustion and the superiority of oil over coal as a fuel is therefore apparent.

However, be you practical man or theorist, engineer or coal passer, the following are worthy of note:

Oil has a certain amount of heat in it in the shape of B.T.U.'s.

This heat is liberated by burning or combustion as it is called.

The water within the boiler should receive the benefit of as much of this heat as possible.

Every unit of heat that is lost through faulty design or otherwise must be replaced.

Everything comes back to the fuel pile.

THE FIREMAN AT THE FURNACE

The firemen at the furnaces regulating the burners cannot see the smoke, and probably would not be interested in gas analysis. His only guide would be the color of the fire as seen through the peep holes. As is stated, if the flame is white so that the back walls can be seen through it there is an excess of air. If it is a dark yellowish-red color, there is not enough air. If it is yellowish-white, the air is just about right.

When steam is available on one boiler, the operation of lighting off the other boilers is greatly simplified. The same precaution against flare backs should be taken.

THE CARE OF BURNERS

Should a burner suddenly go out, the cause will probably be water in the oil, solid matter lodging in the tip orifice, or the carbonization of the oil in the burner. A deficient supply of air, or the intermittent use of burners will cause the oil to carbonize. A dirty streak in the cone spray as seen through the peep hole, or streaks in the light brownish haze at the top of the smoke stack, indicates a dirty burner. Such a burner should be replaced by a clean one immediately.

The dirty burner should be completely disassembled and thoroughly cleaned with kerosene. Burners of the spiral thread type should be examined to see that the thread is not worn or scored. Burners of all types should be examined occasionally to see that the tips are not badly worn or scored. A burner tip will wear in continued use and may be scored by solid matter contained in the oil.

Irregularities either on the inside or outside of burner tips cause irregularities in the oil spray which results in incomplete combustion, and consequent waste. Such burner tips should be polished using a hard wood stick and a paste of oil and finely powdered glass. Emery is too coarse and will score the tip.

Separate sticks should be used for the inside and outside of the tip. These sticks should be filed down to fit the orifice, and should be chucked in a lathe, the tip being held in the hand during the polishing.

In a hurry up job, foreign matter may be blown out of burners with a steam jet.

After the burners are reassembled, they should be tested for tightness, by connecting them to any source of water pressure equal to the working oil pressure. The feed pumps are probably the most convenient source of such pressure. Defects in the spray or leaks in the joints can be quickly detected in this way.

SHUTTING DOWN

When steam is no longer required on a boiler, the oil service pump should be slowed down and the burner cut out one at a time, and their air registers closed. The oil heater should be by-passed so as not to heat the reduced supply of oil too highly. *The boiler feed* must be watched as cutting out burners causes the water in the *gage glass to drop.* It should never be allowed to drop *out of sight.* When all burners have been cut out, the master valve should be closed tight and padlocked, and the oil service pump stopped. All air registers, doors, and other openings to the furnace should be closed tightly to prevent the access of cold air to the hot interior, as sudden cooling will warp the tubes.

ECONOMICAL CONSIDERATIONS

The responsibility for the economical operation of an oil burning plant rests with the chief engineer. In the merchant marine the boilers are usually operated at full power. Economical operation depends almost wholly upon the proper regulation of the air supply. The chief engineer must determnie what opening of the air register is necessary to insure the proper air velocity to prevent panting, and at the same time determine the air pressure necessary to supply enough air to insure complete combustion at this velocity. In others words, he must have the proper balance between the air pressure and velocity. It is quite possible that at a certain air pressure in a closed fire room, enough air would pass the registers to insure complete combustion, but might not be at a velocity sufficient to mix thoroughly with the oil and panting would result. If corrected by speeding the blowers only, without adjusting the registers, it is apparent that too much air would enter with a consequent loss, which would manifest itself in an increase in the smoke stack temperature. The engineer must be on the lookout and promptly correct any such condition.

The ordinary way to obtain the proper balance is to open the registers about two-thirds and speed up the blowers until there is no vibration. Then gradually close the registers until the smoke is of a light brownish-gray color.

The color of the smoke, the appearance of the flame, and the gas analysis outfit all used in combination, afford means whereby the engineer is able to operate at the highest economy.

DANGERS

Oil burning is the most satisfactory installation afloat. It is very simple to operate and, if anything, is safer than coal, provided reasonable precautions are taken.

A flareback is caused by explosion of a mixture of air and oil vapor in the furnace. It is most likely to occur when lighting up, or in attempting to light a burner from the hot brick wall. A flareback may burn the firemen, and may cause damage to the boiler and its fittings.

In case of a flareback, close the master valve at once, shutting off all oil to the boiler. Speed up the blower, if in use, and stop the oil service pump.

TO PREVENT FLAREBACKS

Never allow oil to accumulate in the furnace. If any does accumulate from a leak or other cause, wipe up the oil and blow through the furnace to clear it of vapor before lighting the burners. With natural draft this can be done with a steam hose.

Never attempt to light a burner from a red hot brick wall.

Never stand directly in front of a burner when lighting with the torch. Always stand off to one side to avoid injury in case of flareback.

FIRE

A fire may be caused by the ignition of oil or oil vapor in any place in the ship where leaking oil is liable to collect.

An oil fire cannot be extinguished *by water.* Water will only spread the burning oil over a larger area. Oil fire can be extinguished by smothering with sand, or with chemical fire extinguishers.

The necessity for absolutely tight joints in all oil lines has already been mentioned.

Never tamper with a tight joint, unless it is necessary to take it down. You may have much trouble in making it tight again. If a rivet leaks only the most careful calking will make it tight. Ordinary calking will only make it worse.

Never allow oil to accumulate in any place. Particular care must be taken to prevent an accumulation in the furnaces, on the floor plates, or in the bilges. Spilled oil should be wiped up immediately.

The leakage of some oil into the bilges cannot be prevented. This oil serves a useful purpose as it will protect the metal from corrosion better than red lead. It is not usually necessary to paint the fire room bilges of an oil burning vessel. Oil vapor is heavier than air and tends to accumulate in low levels.

The accumulation of oil vapor in the bilges is especially dangerous, and the careful engineer will wash and pump out the bilges at least once a day simply as a safety precaution.

Always stop oil leaks immediately whenever discovered.

In care of fire use the steam hose, sand, or chemical extinguishers, or better use all three. *Never* use water.

If the fire is so extensive that it cannot be extinguished by these means, shut and seal as tightly as possible every source of air supply. Connect a steam hose to the compartment and smother the fire with steam.

THE CARE OF OIL TANKS

Oil tanks must be kept tight. They must be cleaned about once a year, by wiping out the oil scum and sediment which might clog the strainers. Needless to say, waste should never be used for this purpose as the threads will surely clog the strainers.

Storage tanks are usually fitted with a salt water connection for ballast purposes, and a steam connection for fire purposes. Occasionally heating coils are installed.

Never *enter,* or allow any one else to enter, the empty fuel oil tanks for any purpose, until it has been cleared of gas by steaming out or flooding with water. Steaming is the best, but may be inadvisable on account of the heating of adjacent compartments. In flooding, the tank should be filled to overflowing in order to remove the oil on top of the water. Otherwise the oil will settle on the bottom of the tank when the water is pumped out.

When the tanks are empty the steam heating coils should be tested under steam and examined for leaks. Leaking coils are a source of free water in the oil and trouble at the burners.

LAST BUT NOT LEAST

Exercise common sense and take every precaution that good judgment dictates. It is impossible to give specific directions to cover every contingency that may arise. Familiarity breeds contempt, but if you *never get so familiar* that you apply a *lighted match to see if oil vapor will burn* you will find safety and much satisfaction in the operation of *any oil burning installation.*

THE BABCOCK & WILCOX BOILER

The construction of the Babcock & Wilcox marine boiler embodies the same well-known principles as the land or stationary type; freedom of circulation, and economy when forcing, being important factors of both designs.

The tubes forming the heating surface are divided into vertical sections, and, to insure a continuous circulation in one direction, are placed at an inclination of 15° with the horizontal.

By distributing the surface into sectional elements, all danger from unequal expansion due to raising steam quickly, or to sudden cooling, is at once overcome.

Each section is made up of a series of straight tubes, expanded at their ends into corrugated wrought-steel boxes known as headers. As the headers are staggered, the tubes are so disposed that lanes for the sudden escape of the products of combustion are prevented. The hot gases are therefore completely broken up in their passage across the heating surface.

The furnace is directly below the tube bank, and, as arranged for oil fuel, is ideal. Every part except about one-third of the roof, and the oil burners in the front, is lined with fire brick or fire tile. As is well known, this is an ideal arrangement for securing perfect combustion. The sides and back consist of nine inches of fire brick, backed by three inches of high-grade non-conducting material (Nonpareil block). The bottom is a layer of fire brick on top of four inches of non-conducting material. The roof from the front to about two-thirds of the tube length consists of light fire-tile supported on the lower tubes, the remainder affording the exit for the hot gases through the tube bank. The front, except the oil burners, is faced with special fire tile around the burners, and nine inches of fire brick elsewhere.

Extending across the front of the boiler and connected to the upper ends of the headers by 4-inch tubes, is a horizontal steam and water drum of ample dimensions.

As the upper ends of the rear headers are also connected to this drum by horizontal 4-inch tubes, each section is provided with an entirely independent inlet and outlet for water and steam.

Placed across the bottom of the front header ends and connected thereto by similar 4-inch tubes, is a forged steel box of 6-inch square section. This box, situated at the bottom of the bank of tubes, forms a blow-off connection or mud drum through which the boiler may be completely drained.

The circulation of the water is as follows: Heat being applied to the inclined tubes and vapor formed, the water and steam rise to the high end and flow through the up-take headers and horizontal return to the steam and water drum, the path of both water and steam being short and direct; the water evaporated in the tubes and that carried along by the currents induced by the steam bubbles being replaced by water flowing directly from the bottom of the drum downward through the front headers, or downtakes, and into the tubes, part of this water to be in turn evaporated.

Upon entering the drum the steam and circulating water are directed against a baffle plate, which caused the water to be thrown downward, while the steam separator and passes around the ends of the baffle plate to the steam space, from which it is conducted by a perforated dry pipe to the stop valve.

By a roof of light fire tile, supported upon the lower tubes and extending part way over the furnace, the gases evolved from fresh fuel are compelled to flow toward the rear of the boiler, and under the hot tile roof.

As the furnace increases in height approaching the bridge well, the gases have both space and time in which to mix thoroughly and burn before entering the bank of tubes forming the heating surface. By this arrangement a high furnace temperature is established, which is acknowledged by all authorities to be the essential requirement of boiler economy.

The circuitous route which the gases are compelled to follow, in crossing the heating surface three times before exit, causes them to impart to the tubes the greatest possible amount of heat.

The distance traveled by the products of combustion incontact with the heating surface is about sixteen feet, hence food economy is maintained with high rates of combustion, and a low up-take temperature assured; the interval for the absorption of heat, so necessary for economy.

Opposite the end of each tube is an opening, or hand hole, in the header, through which the tube may be examined, cleaned, plugged or renewed; it is closed by a forged-steel plate into which is riveted a 1-inch stud. This plate is faced, and is drawn to a faced seat by a forged-steel bridge and nut, the joint being made on the inside of the header, by means of a thin gasket.

Should a tube be found defective, from whatever causes, it may be renewed or temporarily plugged, as both ends are accessible. All necessary repairs can be made by the ship's staff. The only tools required are a ripping chisel and an ordinary expander, the operation of which is familiar to every engineer.

The placing of the steam and water drum horizontal with its center on the water-line of the boiler, provides a large body of water where it is most needed, and where changes in the volume of water carried least affect the levels in the gauge glasses.

The location of the drum at the front of the boiler renders all valves and fitting accessible and tends to shorten steam pipe connections. Main stop and safety valves, stop and feed check-valves for both main and auxiliary feeds, are flanged directly to nozzle, provided with counter-bored seats and riveted to the drum shell or heads. The longitudinal seams are butted and strapped, and have from four to six rows of rivets, as the steam pressure requires.

The rivet holes are drilled after the rolled plates are assembled; the butt straps are then removed from the drum plates and all burrs cleaned off. The rivets are driven by hydraulic pressure and held until cool.

The drum heads are formed in a single heat, by hydraulic pressure, to a spherical surface whose radius is equal to the diameter of the shell. The manhole is flanged in the shell plate, or drum head, with a stiffening ring of sufficient thickness to form, with the edge of the plate, a seat for the manhole gasket one inch wide. The manhole plates are 11 x 15 inches, and are faced to a true oval to fit the manhole.

Surrounding the pressure parts, and firmly bolted to the foundation, is a structural iron framing to which the casing plates are fastened.

The spaces between the side tubes are filled with light fire tiles, made of highly refractory fire clay. Against these are placed asbestos millboard and Nonpareil block covering. On the outside, firmly holding the non-conducting materials in position, are the casing plates, which are clamped to the structural framing by butt straps. This method of fastening allows of easy removal, and on replacing makes an air-tight joint without the use of additional packing.

Hinged to the framing at the front and rear of the boiler are large doors, giving access to the hand-hole plates covering the tube ends.

Means are provided for blowing the soot from the exterior of the tubes. A steam lance may be inserted through small dusting doors empaneled in the side casing, as shown above, and communicating with the spaces between the rows of tubes. Each opening is covered by a shutter sliding vertically, which can be opened and shut by the lance. As the seat for this shutter is beveled, it tends on falling to wedge itself into position, thereby making an air-tight joint. This panel is used on the 4-inch tube boilers.

As all cleaning of soot from the exterior of the tubes is performed from the sides, the continuous steaming of the boiler is not in any way hindered.

BABCOCK & WILCOX SUPERHEATERS

As the name implies, the object of the superheater is to supply additional heat to the steam beyond that which is imparted in the boiler. To increase the temperature without increasing the pressure, it is necessary that the heat should be applied to the steam in a separate vessel or container.

The superheater is located above the regular boiler tubes, in an extension of the boiler casing, and at the back of the boiler, above the first and second passes for the hot gases, so that the superheater tubes are subjected to a temperature of from 900° to 1,200° F., depending on the rate of combustion in the boiler. This is a much more favorable location than the one which formerly obtained with scotch boiler, where the superheater was located in the uptake, and with a much lower temperature if the boiler was at all efficient.

The superheater consists of a series of U-shaped tubes, two inches in external diameter, expanded at their ends into two headers, which are on one side of the boiler, while the bend of the "U" is at the opposite side of the boiler, the superheaetr tubes being disposed at right-angles to those of the boiler, and extending practically the entire width of the boiler. Steam is admitted to one of the headers by a pipe connecting with the dry-pipe of the boiler, whence it passes through the U-tubes to the other header, from which the superheated steam is piped to the turbines and other machinery. Handholes are provided in the headers, through which the tubes can be expanded and examined at any time.

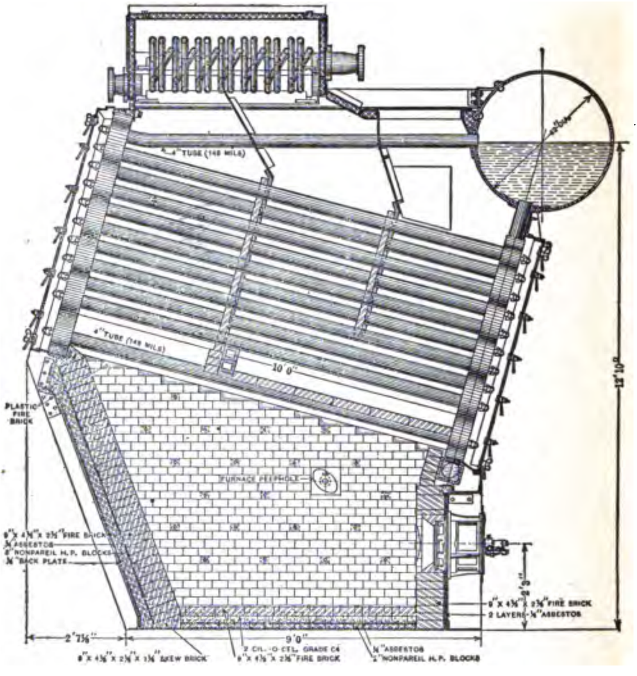

FIG. 14

B. & W. Oil Burning Boiler and Superheater

The total amount of superheating surface is 10% of the boiler heating surface. Under average conditions of operation, the superheat will be from 60° to 80° F. above the temperature of saturated steam.

The purpose of superheated steam is to secure a greater economy in the motive machinery, due to the higher temperature. In practice, there is a gain in economy of about 1% for each 10° F. of superheat, and there is practically the same economy in fuel.

PREPARING BOILERS FOR USE

It is assumed that the boiler is in good working order and has been recently overhauled, so that all parts are in good condition.

All openings, such as handhole and manhole plates, drain cocks, bottom and surface blows, etc., should be examined to see that they are tightly closed. Safety valves, boiler stop valves, feed stop and check valves should be examined by actual moving to see that they are in order. Water gauges and test cocks should be tested to see that they are in working order. The boiler-drum should be a little less than half-ful of water. When testing the try-cocks see that the water corresponds to the same level in the gauge glass. The main stop valves must not be closed too hard; if they are, they are liable to jam from expansion when warming up.

Open air-cocks when boiler is being pumped down to steaming level and see that they are kept open until steam forms; then close them.

With oil-fired boilers it is possible to start all the burners at once, but this should never be done except in an emergency. Although the Babcock & Wilcox boiler will stand extremely severe heat treatment, it should receive the same careful use as any other valuable structure, and consequently in ordinary service the burners should be lighted successively, and only enough at first to raise steam gradually and provide the necessary amount for preliminary handling of the machinery.

When the furnace brickwork is new, or when extensive repairs have just been made, the furnace should be heated gradually.

While steam is forming, attention should be given to all the boiler fittings and feed arrangements to insure that they are in good working order. Special care should be taken to set up on the nuts of any manhole or handhole fittings which may have been taken off for examination or cleaning, and, in general, these nuts should be set up to compensate for softening of gaskets, which usually occurs when first heated after disuse. Care should be taken not to set up so hard as to endanger breaking the bolts.

As the water in the boiler expands while steam is forming the water level will rise. Use the surface blow to keep water at correct level.

Always give careful attention to the steam gauge to be sure that pressure shows when steam forms and issues from the air-cock. If no pressure shows, examination should be made at once to see that the cock between gauge and boiler is open.

Whenever steam is raised on a boiler, and particularly if the safety valves have been overhauled during the interval since last work, these valves should be given careful attention and the steam pressure should be allowed to rise until the valves should lift, if properly adjusted. It may be more convenient to do this, after the boiler has been connected to the main line, but unless the safety valves have been correctly adjusted, the burners should be shut off and the stop valve closed until this is accomplished. Careful attention must be given to the water-gauge glass valves to see that they are open, and this should be insured by also testing the gauge cocks. It cannot be too strongly emphasized that while the gauge-glass is a more convenient record of the water level, the gauge cocks are more absolutely reliable and they should be tested every hour while the boiler is in use.

After steam has been raised with the care noted in the preceding paragraph, the boiler should be connected with the main steam line when there is a difference in pressure of less than ten pounds. The boiler stop valves should first be only slightly cracked to allow the pressures in the steam line and in the boiler to equalize gradually. After the pressures are equalized the stop valves should be opened gradually. If by-pass valves are fitted around the main steam stop valves they should be opened first, the line warmed up and the pressure equalized before the large valves are opened. The drain valves should be opened when any change is made in the steam pressure on the main steam pipe. Experience has shown that these valves should be given a good opening, so that if there is any water in the pipe, it can be blown out in a steady stream so as to prevent "water hammer."

OPERATION OF BOILERS

The feed water should be admitted as uniformly as possible and the effort should be to adjust the check valves so that they will not need constant regulation. When getting under way, commence by opening all check valves, and to the same extent. Feed stop valves should be used to regulate the amount of water admitted.

The water level should be kept about the middle of the gauge-glass. Sudden fluctuations of the water level are detrimental, but there is always some movement of the water up and down in the gauge-glass. As long as a boiler is furnishing steam, the feed supply should never be entirely shut off, even for a short period. When the vessel is maneuvering and the engine speed is constantly changed, it will, of course, be necessary to give special attention to the water-level. Adjustments of feed stop valves should be made gradually and as frequently as necessary.

Oil-fired boilers have the great advantage over those using coal, that it is possible in case of necessity to shut off entirely the source of heat at a moment's notice. Consequently, one of the greatest dangers in a coal-fired boiler, namely, burning the heating surface in case of low water, should never be allowed to occur. If low water occurs, the oil burners can be shut off instantly, thereby remvoing any danger of burning.

In the same way, if there is any sudden reduction in the demand for steam due to a slowing down or stoppage of the machinery, some or all of the burners may be shut off so as to keep the steam pressure within control.

As will be stated elsewhere, the greatest care should be taken ordinarily to prevent any salt water getting in the boilers. However, there may be cases of great emergency where the admission of salt water is justifiable. If, for example, everything is being driven at full-power and it is known that any reduction in power may be disastrous (as in the case of a lee shore in a gale), and there should be a sudden failure of the feed supply, it would be justifiable to use salt water to maintain the water-level for a short time. This would probably cause priming, which is very undesirable, but in the case of turbine this will not cause a disastrous effect, as might be the case with reciprocating engines. This is a very serious matter and should never be resorted to except when the closing down of the boiler, due to the failure of the regular feed supply, would jeopardize the safety of the vessel.

Water should be retained in the boilers without changing as long as practicable, whether they are steaming or idle. They should be run down or emptied only when necessary for examination, cleaning or overhauling, and the water should be changed only when it has become unfit for further use by reason of being dirty, acid or salt. Blow-valves should not be used by routine, but for a specific purpose. As long as the water in the boiler is alkaline the bottom blow should not be used to reduce saturation until the salinity is more than 250 grains of chlorine per gallon.

When the boilers are to be laid off, the bottom blow should be used for a short time simply to remove sediment from the bottom of the boilers.

Sometimes, owing to condenser leaks or other causes, a certain amount of salt water is unavoidably introduced into the boiler. In such cases the bottom blows may be used for a few seconds only, at intervals of four hours. When so used they should be opened wide and closed again quickly. This use of the bottom blow should not be resorted to unless the salinity exceeds 250 grains of chlorine per gallon.

When a boiler is to be shut off, internal accumulations of dirt should first be removed, by the use of the blow valves, and the boiler then pumped up again to the usual level, unless it needs emptying to carry out repairs.

Care should be taken to remove as far as possible, by means of the steam lance or brushes, any deposits of soot from among the tubes.

When it is probable that the boilers will be idle for a long time and not open for examination, they should be kept quite full of fresh water made slightly alkaline. The boilers should be pumped full within 24 hours of completion of steaming, and should be kept so until 24 hours before being again needed. This does not apply, of course, to short stays in port.

The object of the foregoing treatment is to prevent serious internal corrosion of the boilers. Experience has shown that even with the water slightly alkaline there will be a very slight amount of corrosion, but which will not have any serious effect.

Care should be taken to keep the exterior of the tubes and other parts of the boiler dry and free from moisture.

When opportunity offers, and at least once in two months, the interior of the boilers should be examined to determine whether they are clean. Impurities which had been floating in the water and which have not been removed by the surface blow before steam pressure is removed, may be cleared out of the tubes with a wire brush. Grease may be removed to a limited extent by swabbing out the tubes with kerosene. If any large amount of grease is present, the boilers should be closed, filled with water, made considerably alkaline by soda and boiled out.

Scale is most likely to be found in the lower rows of tubes, and, when present, should be removed with turbine cleaners.

In a preliminary inspection, it is not necessary to examine every tube, but handhole plates should be removed in various parts of the tube bank so as to determine conditions. If this inspection shows scale, grease or other dirty condition, then, of course, a thorough inspection and cleaning should be made.

Dampers leading to idle boilers should be kept closed, as well as openings into the furnace, uptake and breeching.

CLEANING

The efficiency of boilers must be preserved by keeping the heating surface clean, both externally and internally. By means of a steam lance and a flexible hose, provided with the boilers, the soot may be almost entirely removed from the tubes, the lance being inserted through the dusting doors in the side casing. In this way the boilers may be cleaned without interfering with the stoking. On arriving in port, the boilers should be swept out, and all deposits of soot removed.

When time in port will permit, the handhole plates opposite the tubes in the vicinity of the furnaces should be removed, and the interior surfaces examined and washed out; and, if any undue accumulation of scale has taken place, it should be removed by the spoon scrapers, wire brush or turbine cleaner as may be necessary.

Tubes have been known to blister and bulge, and upon removal found to contain only an egg-shell of scale thinly deposited over their entire inner surface. Had these tubes been closely examined before removal, by means of an electric lamp or torch, a small laminated hummock of scale would have been discovered directly over the blister or bulge. These small bunches are composed of flakes of scale that have become loosened from other parts of the boiler and carried with the circulation until dammed in some portion of the tube. As these bunches are loose, they may be easily dislodged by washing out with a hose. Scale burns are most likely to occur when the feed water contains sulphate of lime or when salt water is used for make-up feed.

If the water has a tendency to form a hard scale, such a scale should be removed with the tube scrapers or turbine cleaners provided. One thirty-second of an inch of scale is the maximum thickness that should be allowed upon the heating surface.

CORROSION—CAUSES AND PREVENTIVE MEASURES

The principal causes of corrosion of iron and steel boilers, in sea-going vessels, can be classified as follows:

1st—Use of sea water.
2nd—Admixture of air with the feed water.
3rd—Galvanic action.

Each of these causes of corrosion, and means of preventing or remedying them, will be considered separately.

USE OF SEA WATER

Salt water is known to be a solvent of iron or steel, and when boiled under high pressure the magnesia chloride, about 250 grains of which are contained in every gallon, becomes highly corrosive.

Under certain conditions, particularly in the process of corrosion, the water becomes acid by the dissociation of magnesium chloride into hydrochloric acid and magnesia; the acid, in contact with iron not protected by scale, forms an iron salt which, at the very moment of formation, is neutralized by the free magnesia in the water, thereby precipitating oxide of iron and reforming magnesium chloride. Thus it is easily seen that free iron is never found in solution in boiler water. The black and red deposits formed in boilers which have had an excess of sea water in them are generally iron oxides. The red is found when there is much air allowed to get into the boiler; the black when little or no air is present.

Preventive. To prevent salt feed, the condensers must be light, and an ample provision made for fresh water "make-up" either by carrying a supply in bulk or by installing an adequate evaporating plant, designed and located so as to operate without priming.

If salt feed does enter the boiler, the quantity must not be increased by "blowing off" water from the boiler, at least not until the saturation has reached 5/32. A high saturation is preferable to a continuous renewal of salt feed, aside from the heat loss of blowing off.

A light scale will reduce the evaporative efficiency of a boiler, in spite of statements to the contrary, and a heavy scale will induce the burning out of parts exposed to the flames.

Remedy. A small amount of salt water is bound to get into the boilers, even under favorable conditions, through priming in the evaporator and slight leakage from the condenser, and it is an excellent plan to constantly use a small quantity of milk of lime to neutralize it. One or two pounds per 1000 indicated horse-power fed per day, in the manner below mentioned, may suffice. The lime used is the ordinary unslaked lime of commerce, and it should be finely powdered and kept in a dry place; for instance, on the uptake gratings.

Milk of lime is a mixture of about one pound of lime to a gallon of water and should be added at times to the water in the filter box.

The Use of Lime. When starting with new boilers on a voyage for the first time, ten pounds of lime should be put into the boilers for every 1000 horse-power (dissolve in water and put in through manhole); and four to six pounds of lime per day for every 1000 horse-power should be passed through the hot well (as milk of lime) for about six days. At the end of the voyage the boilers should be examined to see if they have a thin coating of lime scale on their interior surface. If this is not the case and the water shows an improper color, the use of the lime should be continued.

The rational of the use of lime is the conversion of magnesium chloride, which is corrosive in effect on iron and steel, into magnesia and chloride of calcium, neither of which is corrosive; and the light scale on the surface also prevents the corrosive elements from coming into contact with the iron.

Further precautionary methods must be employed by the marine engineer in order to conquer corrosion. The boiler water should be tested daily, and if found to be acid or to contain a larger amount than 50 grains of chlorine per gallon, a remedy must be applied.

ADMIXTURE OF AIR WITH FEED WATER

Air has been a well recognized cause of corrosion for many years, and instances of rapid corrosion have been proved to have been caused [illegible]e feed pumps sucking air from the hot well, [illegible]ed being delivered at a level consider[illegible]w the water-line. The boilers that have [illegible] free from this kind of corrosion are those in which the best means have been adopted to keep out air.

Small bubbles of air expelled from the water on boiling attach themselves tenaciously to the heating surfaces. The oxygen in this air at once begins war on the iron or steel and forms iron rust; making a thin crust or excrescence, which, when washed away by the circulation or dislodged by expansion and contraction leaves beneath a small hole or pit. Pitting, once started, progresses rapidly, as the indentations form ideal resting places for the bubbles of air, and at the same time present increased surfaces to be attacked.

With independent feed pumps there is less opportunity for air to get into the boilers than when the pumps are worked off the engines. Air or oxygen is most corrosive in its action, and this is the reason for the boiler feed delivery pipes being fixed either in the steam space or near the water-line.

Preventive. Where possible, the hot well water should be pumped to a filter tank situated eight to ten feet above the feed pump suction valves. By so doing a large amount of air rises and is liberated from the surface of the water, and a head of water at the suction valves of the pump is assured.

Remedy. Salt water absorbs more air than fresh water. Care should be taken to keep the pump glands tight, and to efficiently entrap air in the air vessels.

GALVANIC ACTION

Formerly, nearly all corrosion in boilers was attributed to this cause, and zinc slabs were suspended everywhere possible within the water space. The position of zinc relative to that of iron in the scale of electro-positive metals, causes it to be attacked instead of the metal of the boiler when galvanize action takes place.

Preventive. To afford protection by the use of zinc, however, there must be positive metallic contact between the zinc and iron. Practically, it is impossible to maintain this contact with the usual methods of installation, and it has been shown that no galvanize current exists after a few hours of steaming, in the arrangements ordinarily employed.

Remedy. The use of zinc, however, should not be abandoned on this account, as it appears still a very important element of protection against corrosion due to air in feed water. Its suspension in drums, and points within the boiler near the entrance of the feed, is recommended as of positive benefit, and, indeed, as long as zinc slabs continue to disintegrate and oxidize in a boiler, they deflect to themselves from the iron just that amount of harmful action.

METHOD OF TESTING WATER FOR CORROSIVENESS

The first thing in testing, as is well known, is to see that the color of the water, as shown in the gauge glass, is neither black nor red. The only color admissable is slightly dirty gray or straw color, unless the water is transparent. So long as the water is red or black, corrosion is going on, and it must immediately be neutralized by freely using lime or soda, and frequently scumming and blowing off, the make-up being provided by the evaporator.

The salinometer is not a very accurate instrument for determining the quantity of sea water in boiler water, but the apparatus here described gives a convenient and accurate method of ascertaining the exact number of grains of chlorine per gallon in the water tested. It is based on the scheme for the volumetric determination of chlorine devised by Mr. Mohr, an eminent chemist, and requires one graduated bottle, one bottle of silver solution containing 4.738 grams of silver nitrate to 1000 grams of distilled water, and one bottle of chromate indicator, which is a ten per cent. solution of pure neutral potassium chromate.

To Make Test. Fill the graduated bottle to the zero mark with the water to be tested; add one drop of the chromate indicator; then slowly add the silver solution; keep shaking the bottle. On nearing the full amount of silver solution required, the water will turn red for a moment, and then back to yellow again when shaken. The moment it turns red and *remains red,* stop adding the silver. The reading on the graduated bottle at the level of the liquid will then show the amount of chlorine in grains per gallon. For example, if a permanent red color is shown when the level is midway between 150 and 200, there are 175 grains of chlorine per gallon.

The principle of the process depends upon the fact that if some of this silver solution be dropped into water containing a chloride, a curdy white precipitate of chloride of silver will be formed. If there is also present in the water enough potassium chromate to give a yellow color, the white precipitate will continue to form as before, owing to the silver having a greater affinity for chlorine than for the chromic acid in the chromate. But, at the moment when all the chlorine in the sample has been converted, the silver will attach the yellow potassium chromate, and chromate of silver will be formed, which is red in color. The amount of chlorine present is, therefore, shown by the amount of silver solution required to convert it all to silver chloride, and the determination of the exact point at which the chloride precipitate ceases to form is greatly facilitated by observing when the chromate indicator turns from yellow to red.

It is not necessary to add the silver solution until the color becomes very red, as the delicacy of the reaction would be destroyed, but the change from yellow to yellowish red must be distinct and must not change on shaking. The sample of water to be tested should be neutral, as free acids dissolve the silver chromate. If it should be acid, neutralize by adding sodium carbonate. Slight alkalinity does not interfere with the reaction, but should the sample be very alkaline, it may be neutralized with nitric acid.

Should it happen that the color does not change within the limits of the graduations, the sample may be tested by diluting with distilled water For example, add three parts of distilled water to one part of the sample. If then, on testing the mixture, the color changes 200, the number of grains per gallon in the original sample will be four times this reading, or 800 grains.

The chlorine should be kept down to the possible amount—*say below* 50 *grains per gallon*—as, the nearer the boiler water is to fresh water the safer the boilers are against corrosion.

If the water is so corrosive as to be acid, blue litmus paper, which has not been allowed to become deteriorated through exposure to the atmosphere (keep in a bottle with a glass stopper) will turn slightly red. If a change in color is not apparent at once, it should be allowed to remain in the solution a few minutes and then carefully dried and compared with an unused sample.

Another method is to put into it a few drops of a chemical called methyl-orange. This methyl-orange gives a yellow color so long as the water is alkaline, but if turned pink it shows that the water is acid, and therefore highly corrosive. This latter test is more sensitive than the litmus paper test, and should be used in preference.

THE MARINE TURBINE

Many of the new ships are being fitted with turbine drive and a brief description of this new prime mover will not be out of place in an article of this kind.

There are two fundamental types of turbines, impulse and reaction, and all of the well known makes are either one or the other, or a combination of both.

In the impulse turbine, the steam is expanded from boiler pressure in stationary nozzles. By thus expanding it increases its rate of flow, and leaving the nozzles strikes the blades with terrific force causing them to revolve. The operation is repeated through the various rows of blades and pressure stages until the steam is down to condenser pressure, having exhausted its energy within the blades, which is returned in the form of work by the engine. Thus the impulse turbine works or revolves by the actual impact or force of the steam upon the blades. The G. E. and De Laval turbines are of the impulse type.

The reaction turbine works on an entirely different principle. In this type the steam is expanded mainly in the moving blades themselves and the expansion causes a gain in the velocity of the steam. The difference in the velocity of the steam at the point of starting expansion and the base of the blade, acts in "reactive" manner and causes the bladed rotor to revolve. In the author's work "The Marine Turbine and Steam Power Plant" the fundamental and practical actions of the two types, as well as gears, auxiliaries, etc., are thoroughly treated.

The mixed turbine is one where an impulse element is utilized in the H.P. end and the reaction blades follow. The reason for this is that the blades of an all reaction turbine in the H.P. end would have to be very small as the volume of the H.P. steam is not very great.

As the expansion of steam takes place within the blades in the reaction turbine, it is important that the leakage over the tips be as small as possible. With a very small blade, no matter how small the tip clearance was, the loss due to leakage would be large in proportion to the amount of steam performing work upon the blades.

With an impulse element in the H.P. end, the steam is expanded in the nozzles and used impulse manner first, and when it enters the reaction blades its volume is much greater, due to its lower pressure. Thus a large blade can be used and the loss due to tip leakage is not so great in proportion to the amount performing work upon the blades.

High vacuum is a necessity in turbine practice, as the main economy of the engine is based upon the fact that it can use the steam down to a perfect vacuum (if it were possible to get one).

In the reciprocating engine this is almost impossible because the H.P. cylinder would have to be made "twice as large." In order to handle the enormous volume of steam at very low pressures, it must be borne in mind that between two pounds absolute (which means two pounds above a perfect vacuum) and one pound absolute, the volume of steam "doubles."

The reciprocating engine can handle steam down to a pressure corresponding to about 26 inches of vacuum successfully and economically. It is not advisable to carry more than 26 inches, on account of the great increase in the volume of the steam below that. The turbine can handle the volumes of low pressure steam as it has great numbers of blades and a slight area added to each blade will take care of the situation.

The astern element of any turbine is mounted at the after end of the rotor and revolves in a vacuum. The blades are set just oppositely to those of the ahead element and if the vacuum is low, the astern blades will become heated when running under ahead motion by bucking the pressure. The astern element is not as elaborate as the ahead, because the engine is running ahead most of the time and it is not advisable to have great layouts which must be carried dead.

The turbine engine is fundamentally a high-speed engine and it has been found that a high speed propeller is not practicable. This is overcome by reduction gears which allow the turbine to be revolved at high speed and the propeller at low speed. Thus both turbine and propeller can operate at their most economical speeds and the economy of the installation suffers no loss on this account.

BURNING OIL FUEL

The requirements for burning petroleum are as follows:

1st. Its atomization must be thorough.

2nd. When atomized it must be brought into contact with the requisite quantity of air for its combustion, and this quantity must be at the same time a minimum to obviate loss in stack gases.

3rd. The mixture must be burned in a furnace where a refactory material radiates heat to assist in the combustion, and the furnace must stand up under the high temperatures developed.

4th. The combustion must be completed before the gases come into contact with the heating surfaces or otherwise the flame will be extinguished, possibly to ignite later in the flue connection or in the stack.

5th. There must be no localization of the heat on certain portions of the heating surfaces or trouble will result from overheating and blistering.

The first requirement is met by the selection of a proper burner.

The second requirement is fulfilled by properly introducing the air into the furnace, either through checkerwork under the burner or through openings around them, and by controlling the quantity of air to meet variations in furnace conditions.

The third requirement is provided for by installing a furnace so designed as to give a sufficient area of heated brickwork to radiate the heat required to maintain a proper furnace temperature.

The fourth requirement is provided for by giving ample space for the combustion of the mixture of atomized oil and air, and a gas travel of sufficient length to insure that this combustion be completed before the gases strike the heating surfaces.

The fifth requirement is fulfilled by the adoption of a suitable burner in connection with the furnace meeting the other requirements. A burner must be used from which the flame will not impinge directly on the heating surface and must be located where such action cannot take place. If suitable burners properly located are not used, not only is the heat localized with disastrous results, but the efficiency is lowered by the cooling of the gases before combustion is completed.

OIL BURNERS

The functions of an oil burner is to atomize or vaporize the fuel so that it may be burned like a gas. All burners may be classified under three general types: 1st, spray burners, in which the oil is atomized by steam or compressed air; 2nd, vapor burners, in which the oil is converted into vapor and then passed into the furnace; 3rd, mechanical burners, in which the oil is atomized by submitting it to a high pressure and passing it through a small orifice.

Vapor burners have never been in general use and will not be discussed.

Spray burners are almost universally used for land practice and the simplicity of the steam atomizer and the excellent economy of the better types, together with the low oil pressure and temperature required makes this type a favorite for stationary plants, where the loss of fresh water is not a vital consideration. In marine work, or in any case where it is advisable to save feed water that otherwise would have to be added in the form of "make-up," either compressed air or mechanical means are used for atomization. Spray burners using compressed air as the atomizing agent are in satisfactory operation in some plants, but their use is not general. Where there is no necessity of saving raw feed water, the greater simplicity and economy of the steam spray atomizer is generally the most satisfactory. The air burners require blowers, compressors or other apparatus which occupy space that might be otherwise utilized and require attention that is not necessary where steam is used.

Steam spray burners of the older types had disadvantages in that they were so designed that there was a tendency for the nozzle to clog with sludge or coke formed from the oil by the heat, without means of being readily cleaned. This has been overcome in the more modern types.

Steam spray burners, as now used, may be divided into two classes: 1st, inside mixers; and 2nd, outside mixers. In the former the steam and oil come into contact within the burner and the mixture is atomized in passing through the orifice of the burner nozzle.

In the outside mixing class the steam flows through a narrow slot or horizontal row of small holes in the burner nozzle; the oil flows through a similar slot or hole above the steam orifice, and is picked up by the steam outside of the burner and is atomized. Fig. 5 shows a type of the Babcock & Wilcox burner of this class (formerly known as the Peabody burner), which has here given eminent satisfaction. (The construction is evident from the cut.) It will be noted that the portions of the burner forming the orifice may be readily replaced in case of wear, or if it is desired to alter the form of the flame.

Where burners of the spray type are used, heating the oil is of advantage not only in causing it to be atomized more easily, but in aiding economical combustion. The temperature is, of course, limited by the flash point of the oil used, but within the limit of this temperature there is no danger of decomposition or of carbon deposits on the supply pipes. Such heating should be done close to the boiler to minimize radiation loss. If the temperature is raised to a point where an appreciable vaporization occurs, the oil will flow irregularly from the burner and cause the flame to sputter.

On both steam and air atomizing types, a bypass should be installed between the steam or air and the oil pipes to provide for the blowing out of the oil duct. Strainers should be provided for removing sludge from the fuel and should be so located as to allow for rapid removal, cleaning and replacing.

Mechanical burners have been in use for some time in European countries, but their introduction and use have been of only recent occurrence in the United States. Here as already stated, the means for atomization are purely mechanical. Experiments have been made with flat flame mechanical burners, but their satisfactory action has been confined to instances where it is only necessary to burn a small quantity of oil through each individual burner.

This system of oil burning is especially adapted for marine work as the quantity of steam for putting pressure on the oil is small and the condensed steam may be returned to the system.

The only method by which successful mechanical atomization has been accomplished is one by which the oil is given a whirling motion within the burner tip. This is done either by forcing the oil through a passage of helical form or by delivering it tangentially to a circular chamber from which there is a central outlet. The oil is fed to these burners under a pressure which varies with the make of the burner and the rates at which individual burners are using oil. The oil particles fly off from such a burner in straight lines in the form of a cone rather than in the form of a spiral spray, as might be supposed.

With burners of the mechanical atomizing design, the method of introducing air for combustion and the velocity of this air are of the greatest importance in securing good combustion and in the effects on the character and shape of the flame. Such burners are located at the front of the furnace and various methods have been tried for introducing the air for combustion. Where, in the spray burners, air is ordinarily admitted through a checker work under the burner proper, with the mechanical burner, it is almost universally admitted around the burner. Early experiments with these air distributors were confined largely to single or duplicate cones used with the idea of directing the air to the axis of the burner. A highly successful method of such air introduction, developed by the engineers of The Babcock & Wilcox Co., is by means of what they term an "impeller plate." This consists of a circular metal disk with an opening at the center for the oil burner and with radial metal strips from the center to the periphery turned at an angle which in the later designs may be altered to give the air supply demanded by the rate of combustion.

The air so admitted does not necessarily require a whirling motion, but experiments show that where the air is brought into contact with the oil spray with the right "twist," better combustion is secured and lower air pressures and less refinement of adjustment of individual burners are required.

Mechanical burners have a distinct advantage over those in which steam is used as the atomizing agent in that they lend themselves more readily to adjustment under wider variations of load. For a given horse power there will ordinarily be installed a much greater number of mechanical than steam atomizing burners. This in itself is a means to better regulation, for with the steam atomizing burner, if one of a number is shut off, there is a marked decrease in efficiency. This is due to the fact that with the air admitted under the burner, it is ordinarily passing through the checkerwork regardless of whether it is being utilized for combustion or not. With a mechanical burner, on the other hand, where individual burners are shut off, air that would be admitted for such burner, were it in operation, may also be shut off and there will be no undue loss from excess air.

Further adjustment to meet load conditions is possible by a change in the oil pressure acting on all burners at once. A good burner will atomize moderately heavy oil with an oil pressure as low as 30 pounds per square inch and from that point up to 200 pounds or above. The heating of the oil also has an effect on the capacity of individual burners and in this way a third method of adjustment is given. Under working conditions, the oil pressure remaining constant, the capacity of each burner will decrease as the temperature of the oil is increased though at low temperatures the reverse is the case. Some experiments with a Texas crude oil having a flash point of 210 degrees showed that the capacity of a mechanical atomizing burner increased from 80 degrees Fahrenheit to 110 degrees Fahrenheit, from which point it fell off rapidly to 140 degrees and then more slowly to the flash point.

The above methods, together with the regulation possible through manipulation of the boiler dampers, indicate the wide range of load conditions that may be handled with an installation of this class of burners.

As has already been stated, results with mechanical atomizing burners that may be considered very successful have been limited almost entirely to cases where forced blast of some description has been used, the high velocity of the air entering being of material assistance in securing the proper mixture of air with the oil spray. Much has been done and is being done in the way of experiment with this class of apparatus toward developing a successful mechanical atomizing burner for use with natural draft, and there appears to be no reason why such experiments should not eventually produce satisfactory results.

Steam Consumption of Burners—The Bureau of Steam Engineering, U. S. Navy, made in 1901 an exhaustive series of tests of various oil burners that may be considered as representing, in so far as the performance of the burners themselves is concerned, the practice of that time. These tests showed that a burner utilizing air as an atomizing agent, required for compressing the air from 1.06 to 7.45 per cent of the total steam generated, the average being 3.18 per cent. Four tests of steam atomizing burners showed a consumption of 3.98 to 5.77 per cent of the total steam, the average being 4.8 per cent.

Improvement in burner design has largely reduced the steam consumption, though to a greater degree in steam than in air atomizing burners. Recent experiments show that a good steam atomizing burner will require approximately 2 per cent of the total steam generated by the boiler operated at or about its rated capacity. This figure will decrease as the capacity is increased and is so low as to be practically negligible, except in cases where the question of loss of feed water is all important. There are no figures available as to the actual steam consumption of mechanical atomizing burners but apparently this is small if the requirement is understood to be entirely apart from the steam consumption of the apparatus producing the forced blast.

CAPACITY OF BURNERS

A good steam atomizing burner properly located in a well-designed oil furnace has a capacity of somewhat over 400 horse power. This question of capacity of individual burners is largely one of the proper relation between the number of burners used and the furnace volume. In some recent tests with a Babcock & Wilcox boiler of 640 rated horse power, equipped with three burners, approximately 1350 horse power was developed with an available draft of .55 inch at the damper or 450 horse power per burner. Four burners were also tried in the same furnace but the total steam generated did not exceed 1350 horse power or in this instance 338 horse power per burner.

From the nature of mechanical atomizing burners, individual burners have not as large a capacity as the steam atomizing class. In some tests on a Babcock & Wilcox marine boiler, equipped with mechanical atomizing burners, the maximum horse power developed per burner was approximately 105. Here again the burner capacity is largely one of proper relation between furnace volume and number of burners.

FURNACE DESIGN

Too much stress cannot be laid on the importance of furnace design for the use of this class of fuel. Provided a good type of burner is adopted the furnace arrangement and the method of introducing air for combustion into the furnace are the all important factors. No matter what the type of burner, satisfactory results cannot be secured in a furnace not suited to the fuel.

The Babcock & Wilcox Co. has had much experience with the burning of oil as fuel and an extended series of experiments by its engineers led to the development and adoption of the B. & W. furnace as being most eminently suited for this class of work.

The atomized oil is introduced into the furnace in the direction in which it increases in height. This increase in furnace volume in the direction of the flame insures free expansion and a thorough mixture of the oil with the air, and the consequent complete combustion of the gases before they come into contact with the tube heating surfaces. In such a furnace flat flame burners should be used, in which the flame spreads outward toward the sides in the form of a fan. There is no tendency of the flames to impinge directly on the heating surfaces, and the furnace can handle any quantity of flame without danger of tube difficulties. The burners should be so located that the flames from individual burners do not interfere nor impinge to any extent on the side walls of the furnace, an even distribution of heat being secured in this manner. The burners are operated from the boiler front and peepholes are supplied through which the operator may watch the flame while regulating the burners. The burners can be removed, inspected, or cleaned and replaced in a few minutes. Air is admitted through a checkerwork of fire brick supported on the furnace floor, the openings in the checkerwork being so arranged as to give the best economic results in combustion.

With steam atomizing burners introduced through the front of the boiler in stationary practice, it is usually in the direction in which the furnace decreases in height and it is with such an arrangement that difficulties through the loss of tubes may be expected. With such an arrangement, the flame may impinge directly upon the tube surfaces and tube troubles from this source may arise, particularly where the feed water has a tendency toward rapid scale formation. Such difficulties may be the result of a blowpipe action on the part of the burner, the over heating of the tube due to oil or scale within, or the actual erosion of the metal by particles of oil improperly atomized. Such action need not be anticipated, provided the oil is burned with a short flame. The flames from mechanical atomizing burners have a less velocity of projection than those from steam atomizing burners and if introduced into the higher end of the furnace, should not lead to tube difficulties provided they are properly located and operated. This class of burner also will give the most satisfactory results if introduced so that the flames travel in the direction of increase in furnace volume.

OPERATION OF BURNERS

When burners are not in use, or when they are being started up, care must be taken to prevent oil from flowing and collecting on the floor of the furnace before it is ignited. In starting a burner, the atomized fuel may be ignited by a burning wad of oil-soaked waste held before it on an iron rod. To insure quick ignition, the steam supply should be cut down. But little practice is required to become an adept at lighting an oil fire. When ignition has taken place and the furnace brought to an even heat, the steam should be cut down to the minimum amount required for atomization. This amount can be determined from the appearance of the flame. If sufficient steam is not supplied, particles of burning oil will drop to the furnace floor, giving a scintillating appearance to the flame. The steam valves should be opened just sufficiently to overcome this scintillating action.

AIR SUPPLY

From the nature of the fuel and the method of burning, the quantity of air for combustion may be minimized. As with other fuels, when the amount of air admitted is the minimum which will completely consume the oil, the results are the best. The excess or deficiency of air can be judged by the appearance of the stack or by observing the gases passing through the boiler settings. A perfectly clear stack indicates excess air, whereas smoke indicates a deficiency. With properly designed furnaces the best results are secured by running near the smoking point with a slight haze in the gases. A slight variation in the air supply will affect the furnace conditions in an oil burning boiler more than the same variation where coal is used, and for this reason it is of the utmost importance that flue gas analysis be made frequently on oil-burning boilers. With the air for combustion properly regulated by adjustment of any checkerwork or any other device which may be used, and the dampers carefully set, the flue gas analysis should show, for good furnace conditions, a percentage of CO_2 between 13 and 14 per cent, with either no CO or but a trace.

In boiler plant operation it is difficult to regulate the steam supply to the burners and the damper position to meet sudden and repeated variations in the load. A device has been patented which automatically regulates by means of the boiler pressure the pressure of the steam to the burners, the oil to the burners and the position of the boiler damper. Such a device has been shown to give good results in plant operation where hand regulation is difficult at best, and in many instances is unfortunately not even attempted.

EFFICIENCY WITH OIL

As pointed out in enumerating the advantages of oil fuel over coal, higher efficiencies are obtainable with the former. With boilers of approximately 500 horse power equipped with properly designed furnaces and burners, an efficiency of 83 per cent is possible or making an allowance of 2 per cent for steam used by burners, a net efficiency of 81 per cent. The conditions under which such efficiencies are to be secured are distinctly test conditions in which careful operation is a prime requisite. With furnace conditions that are not conducive to the best combustion, this figure may be decreased by from 5 to 10 per cent. In large properly designed plants, however, the first named efficiency may be approached for uniform running conditions, the nearness to which it is reached depending on the intelligence of the operating crew. It must be remembered that the use of oil fuel presents to the careless operator possibilities for wastefulness much greater than in plants where coal is fired, and it therefore pays to go carefully into this feature.

Table 48 gives some representative tests with oil fuel.

BURNING OIL IN CONNECTION WITH OTHER FUELS

Considerable attention has been recently given to the burning of oil in connection with other fuels, and a combination of this sort may be advisable either with the view to increasing the boiler capacity to assist over peak loads, or to keep the boiler in operation where there is the possibility of a temporary failure of the primary fuel. It would appear from experiments that such a combination gives satisfactory results from the standpoint of both capacity and efficiency, if the two fuels are burned in separate furnaces. Satisfactory results cannot ordinarily be obtained when it is attempted to burn oil fuel in the same furnace as the primary fuel, as it is practically impossible to admit the proper amount of air for combustion for each of the two fuels simultaneously.

TABLE 48

Tests of Babcock and Wilcox Boilers with Oil Fuel

Plant		Pacific Light and Power Company, Los Angeles, Cal.		Pacific Light and Power Company, Redondo, Cal.		Miami Copper Company Miami, Arizona	
Rated Capacity of Boiler	Horse Power	467		604		600	
Duration of Test	Hours	10	10	7	7	10	4
Steam Pressure by Gauge	Pounds	156.4	156.9	184.7	184.9	183.4	189.5
Temperature of Feed Water	Degrees F.	62.6	61.1	93.4	101.2	157.7	156.6
Degrees of Superheat	Degrees F.	......	......	83.7	144.3	103.4	139.6
Factor of Evaporation	....	1.2004	1.2020	1.2227	1.2475	1.1676	1.1886
Draft in Furnace	Inches	.02	.05	.014	.19	.12	.22
Draft at Damper	Inches	.08	.15	.046	.47	.19	.67
Temperature of Exit Gases	Degrees F.	438	525	406	537	430	612
Flue Gas Analysis CO_2	Per Cent	......	......	14.3	12.1	......	......
O	Per Cent	......	......	3.8	6.8	......	......
CO	Per Cent	......	......	0.0	0.0	......	......
Oil Burned per Hour	Pounds	1147	1837	1439	2869	1404	3214
Water Evaporated per Hour from and at 212 Degrees	Pounds	18310	27855	22639	40375	21720	42863
Evaporation from and at 212 Degrees per Pound of Oil	Pounds	15.96	15.16	15.73	14.07	15.47	13.34
Per Cent of Rated Capacity Developed	Pounds	113.6	172.9	108.6	193.8	104.9	207.1
B. t. u. per Pound of Oil	B. t. u.	18626	18518	18326	18096	18600	18600
Efficiency	Per Cent	83.15	79.46	83.29	76.02	80.70	69.6

OIL MEASUREMENT

For the calculation of evaporative results, fuel used for power, heat value, etc., units of weight are employed, i. e., the pound, kilo, etc. (1 kilo = 2.204 pounds avoirdupois); but for measurement of bunkers, cargo tanks and in general sales contracts, the oil is figured by volume; thus, in the United States, the usual units are the U. S. gallon (231 cubic inches = 3.785 litres) and the barrel of 42 gallons. The litre and the Imperial gallon (4.54 litres) are used abroad, where the barrel is figured at 41 Imperial gallons (50 U. S. gallons). The Imperial gallon equals about 1.2 U. S. gallons. I understand that some of our oil companies favor the Imperial barrel (50 U. S. gallons) as a matter of convenience, but 42 gallons is the accepted standard.

For statistical purposes, the ton (2240 pounds) and the "metric ton" or 1,000 kilos (2204 pounds) are frequently used.

Volumetric measurement of oil should always be based on a standard temperature, the usual figure in this country being 62° F. The Navy Department specifies 60° F. and a correction of 0.4 of 1% is made for each 10 degrees variation from this standard.

Oil meters have been frequently installed in the pipe lines to burners, and as a check on consumption they are of value. All meters, however, are liable to error—and it is not always the same error; besides it may easily happen that the piping arrangement is such as to allow the meter to register while circulating the oil through the system preparatory to lighting up, thus vitiating whatever approach to accuracy the meter might possess.

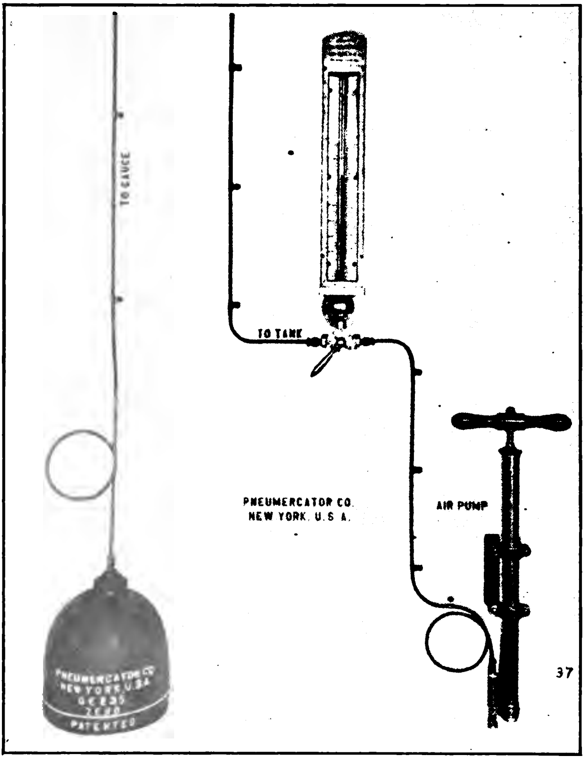

FIG. 15

Tank measurement is in the long run most reliable if properly safeguarded.

An apparatus called a "pneumercator" which seems to offer a very accurate means for tank measurement. This instrument is being applied not only on shipboard, but for shore storage stations as well—and for any sort of liquid measurement in tanks:

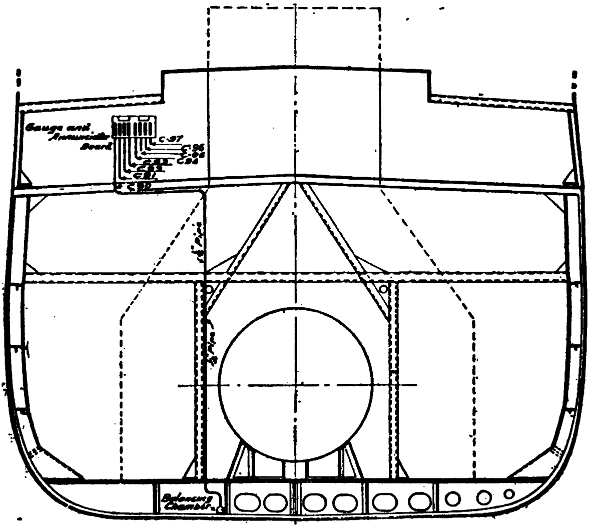

FIG. 16

"The accurate measuring of fuel oil in tanks that are either being filled, or from which oil is being used, is accomplished by means of the Pneumercator.

"The Pneumercator has been adopted by the United States Navy to measure the fuel oil in ship's storage and relay tanks, and is now installed, or about to be installed in all the oil battleships.

"The accuracy of the Pneumercator readings is best illustrated by the following service incident: On the *"New York"* the hourly consumption of Peabody burners was determined by the Pneumercator on several occasions. On the acceptance trial of this vessel the fuel oil burned was accurately measured in tanks on deck, under the charge of the Official Trial Board. This measured hourly burner consumption differed by less than 0.1 gallon from that established by Pneumercator readings."

"PNEUMERCATOR" TANK GAUGES

"Pneumercator" Tank Gauges applied to cargo, fuel, ballast or water tanks or bilges indicate the depth, weight, volume or specific gravity of the tank contents.

They provide perpetual inventory of liquid in tanks.

An accurate check on liquid put in or withdrawn.

In the case of fuel oil, they indicate the quantity on hand, check invoices and indicate the amount consumed per hour or day.

They will operate with equal accuracy on tanks open to atmosphere or under pressure or vacuum. Accuracy is not affected by temperature changes.

There are no floats, diaphragms or delicate mechanism of any kind to stick or get out of order.

The operation of all models of "Pneumercator" Gauges is based on the maintenance of a true hydrostatic balance between the head or depth of liquid to be measured and a column of mercury or other indicating medium. The pressure of the liquid is transmitted to the gauge by air confined in a small connecting tube between the liquid and the gauge.

The Balance Chamber is located at a predetermined point below the surface of the liquid to be measured and with a direct opening to the liquid.

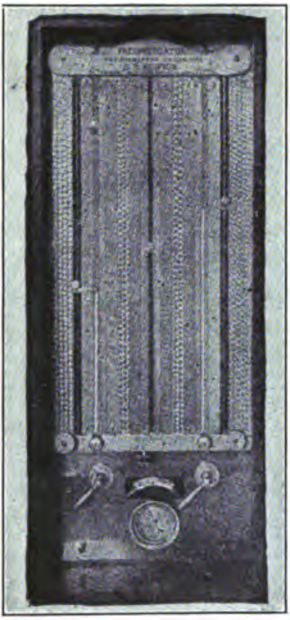

FIG. 17

The liquid trying to enter the Balance Chamber, by its own weight, compresses the air in the chamber, and in the connecting pipe-line to the mercury gauge, thus causing the mercury to rise or fall in direct ratio to the pressure exerted.

The installation of the "Pneumercator" is simple. The small air pipe can be led anywhere, the number of twists, bends, indirect leads or the temperature through which it may be led—whether it be through the boiler room or a refrigerator—have no effect on the accuracy of the reading.

"PNEUMERCATOR" DRAFT GAUGES

"Pneumercator" Draft Gauges indicate the fore and aft draft of the vessel, register the mean draft and corresponding tons displacement.

They weigh bulk cargoes loaded or unloaded with extreme accuracy.

They enable a ship to be loaded to capacity without danger of overloading.

They are invaluable in loading or discharging at night or in rough water.

In case of leaks caused by collision or otherwise they constantly show every variation of trim and draft and whether or not pumps are controlling the inrush of water.

The instrument is working for the owner day and night, because it permits a correct measure of the cargo loaded or discharged. This is impossible by reading the draught figures on the hull of the ship.

With the "Pneumercator" Draught Gauge the draught can be ascertained with accuracy down to the fraction of an inch, whereas the motion of the waves makes any other reading inaccurate, even when the water is comparatively still.

Pneumercator Gauges are manufactured and sold by Pneumercator Co., 15 Park Place, N. Y., and by Kelvin, Bottomley & Baird, Ltd., Glasgow, Scotland.

FUEL OIL—QUESTIONS AND ANSWERS

Q. Name two kinds of oil used for fuel and explain them.

A. Paraffin Base oil and Asphaltum Base oil. Paraffin Base means that when all other products are extracted that which remains is a paraffin Base. The same for Asphaltum Base which, however, is heavier oil than Paraffin. Paraffin oil is found around Pennsylvania and vicinity, while Asphaltum oil comes from Texas and Mexico.

Q. What are some of the advantages of oil burning?

A. Cleaner than coal, increased efficiency, requires less space. Double bottoms and other spaces, which are useless for bunkering coal, can be utilized. Less men needed in the fireroom.

Q. What is meant by the "Flash Point" of oil?

A. It is the temperature at which the oil will give off an inflammable gas.

Q. What is the "Fire Point" of oil?

A. It is the point at which the oil will support combustion.

Q. What are the requirements for the combustion of fuel oil?

A. There are three things necessary for the perfect combustion of fuel oil: they are atomization, fuel gases to be at ignition temperature, quantity and velocity of air.

Q. What is Atomization?

A. The breaking up of fuel oil into minute particles by mechanical means.

Q. Give the three methods of Atomization?

A. Air, steam and mechanical.

Q. What does heavy black smoke issuing from the stack indicate?

A. This condition indicates that poor combustion is taking place. Consequently some of the heat which should be heating the water in the boiler is being wasted.

Q. What does a pure white flame indicate?

A. Generally speaking, it indicates an excessive supply of air within the furnace.

Q. Why are stack temperatures taken?

A. They are taken to correctly gauge the combustion conditions.

Q. What smoke conditions indicate ideal combustion?

A. A light, hazy, brown smoke issuing from the stack would indicate that ideal combustion is taking place.

Q. What is meant by a B.T.U.?

A. A B.T.U. is the abbreviation of a British Thermal Unit and is the standard Unit of heat measurement.

Q. About how many B.T.U.'s of heat are there in a pound of fuel oil?

A. About 19,000.

Q. About how many in a pound of coal?

A. About 14,000.

Q. Why is the supply of oxygen within the furnace so important?

A. Because the small particles of oil will not burn unless mixed with the proper amount of oxygen. This has been repeatedly demonstrated in tests.

Q. Why must fuel oil be treated before being burned?

A. To reduce its viscosity so that it can be pumped and atomized successfully.

Q. What are the advantages of having settling tanks over having the oil pump take its suction from the double bottoms?

A. Short suction for the pump, consequently less danger of losing suction. Loss of suction may result in serious damage.

Q. What is meant by the "viscosity" of oil and how is it measured?

A. "Viscosity" means body or thickness, or may be described as the freedom of the oil to flow. "Saybolt" viscosity is the standard most generally used in this country and is expressed as so many seconds at some given temperature in degrees Fahrenheit.

OIL TERMS AND DATA

Specific Gravity—Specific gravity is defined as the ratio of the weight of a certain volume of a substance to the weight of the same volume of pure water. Thus if one gallon of oil at 60 degrees Fahrenheit weighs 8.044 lbs., and one gallon of water at 60 degrees Fahrenheit weighs

8.331 lbs., the specific gravity of the oil is 8.044 divided by 8.331 = .9655.

Beaumé. When oil is referred to as of a certain Beaumé, it is simply another term for the gravity of the oil. An instrument called a hydrometer with variations from 10 to 100, which when put in a liquid sinks to different depths, according to the gravity of the oil, s themeans of measurement of the gravity in the Beaumé scale. The basic of temperature for testing is 60 degrees Fahrenheit and for other temperatures of the liquid the variations must be calculated. Hydrometers are provided with a scale for figuring the Beaumé for different temperatures other than 60 degrees Fahrenheit. The relation between specific gravity and the Beaumé scale is found by adding the degrees on the Beaumé scale to 130 and dividing the sum by 140.

Flash Point. Flash point is defined as the temperature to which an oil must be heated to give off vapors, which when mixed with air produce an explosive mixture. Oils with a flash point of 150 degrees Fahrenheit and over are safe for storage.

Firing Point. The firing point is defined as the temperature at which oil will give off vapor which when ignited will burn continuously. The firing point is usually about 50 degrees Fahrenheit above the flash point.

Viscosity. Viscosity is a measure of fluidity expressed in seconds and is the time required for a fixed quantity of oil to flow through a given sized orifice as compared to the time required for another liquid to flow through the same orifice, both at fixed temperatures. There are three methods of finding the viscosity in general use: Redwood, Engler, and Saybolt.

Redwood uses: 50 cubic centimeters is the quantity of oil; 70° F. is the temperature; and rape oil is the comparative liquid.

Engler uses: 200 cubic centimeters is the quantity of oil; 20° C. is the temperature; and water is the comparative liquid.

Saybolt uses: A special oil cup is the measure of quantity; 70° F. is the temperature.

There are no fixed coefficients or relations for converting the viscosity of an oil from one system to another.

Cold Test: When the temperature of an oil is lowered, the temperature at which the oil starts to congeal is called the Cold Test.

USEFUL DATA

BOILER HORSE-POWER

A boiler horse-power is a measure of evaporation and is taken arbitrarily as the evaporation of 34.5 lbs. of water per hour from and at 212° F.

RATED BOILER HORSE-POWER

The rated boiler horse-power is given to a boiler of a certain number of square feet of heating surface by the manufacturer. For Scotch boilers and similar types the usual rating is one boiler horse-power for 8 sq. ft. of heating surface. For water tube boilers 10 sq. ft. is usually used and for return tubular and vertical fire tube boilers 12 sq: ft. is common practice.

INDICATED HORSE-POWER

I.H.P. (indicated horse-power) is a measure of power or work done and is equivalent to 33,000 foot pounds of work performed per minute.

WORK

The work necessary to raise one pound one foot is called a foot pound and is the unit of work.

HEAT

A B. T. U. (British Thermal Unit) is the unit of heat and is defined as the heat necessary to raise the temperature of one pound of water one degree Fahrenheit, when the water is at its greatest density 30° F.

CALORIE

A calorie is the unit of heat in the metric system of weights and measurements. One calorie = 3.9683 B. T. U.

MECHANICAL EQUIVALENT OF HEAT

778 foot pounds = one B. T. U.

1 American gallon of fresh water = 8.331 pounds—231 cubic inches.

1 English gallon of fresh water = 10.00 pounds—277.479 cubic inches.

1 Cubic foot of fresh water = 7.4005 American gallons.

1 Cubic foot of fresh water = 62.4 lbs.

1 Inch = 2.54 centimeters.

1 Yard = .9044 meters.

1 Pound = 2.204 kilograms.

1 Pound per square inch pressure =2.305 inches of water head.

1 Atmosphere = 14.7 pounds pressure (atmospheric pressure at sea level).

1 Atmosphere = 33.8 feet of water head.

1 Atmosphere = 29.9 inches of mercury head.

1 Pound of air = 13.14 cubic feet.

FUEL OIL BUNKERING DEPOTS

The United States Shipping Board has furnished the following list of American fuel oil bunkering stations in foreign ports:

St. Thomas, V. I.: Capacity, 2 tanks, total 110,000 barrels. Station operated by United States Shipping Board.

Brest, France: Capacity, 3 tanks, total 165,000 barrels. Operated under special agreement with French Naval Authorities.

Ponta del Gada: Wooden tank barge *Wasagya* capacity 25,000 barrels, serving as temporary bunkering station until negotiations to secure concession for permanent station are completed.

Cape Verde Islands: Upon establishment of permanent station at the Azores, the tank barge

Wasagya to act as temporary station Cape Verde Islands.

Bizerta, Algiers: Capacity, 3 tanks, total 165,000 barrels. Station operated under leasing arrangement with Societa Italo Americana Pel Petrolio.

Constantinople: Capacity 3 tanks, total 104,000 barrels. Leasing arrangement with Standard Oil Co. of New York.

Colombo: Capacity, 3 tanks, total 165,000 barrels. Leasing arrangements with Standarl Oil Co. of New York.

Shanghai: Capacity, 3 tanks, total 165,000 barrels. Leasing arrangement with Standard Oil Co. of New York.

Manila: Capacity, 2 tanks, total 110,000 barrels. Station erected and operated by United States Shipping Board.

Honolulu: Capacity, 2 tanks, total 110,000 barrels. Station erected and operated by United States Shipping Board on leased land.

Durban: Capacity, 3 tanks, total 165,000 barrels. Leasing arrangement with Vacuum Oil Company.

Sydney: Capacity undetermined. Leasing arrangement with Vacuum Oil Company.

Rio de Janeiro: Capacity 100,000 barrels. Leasing arrangement with West India Oil Company.

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